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Hazardous Waste Management System: General Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilites; and Hazardous Waste Permit Program

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BACKGROUND DOCUMENT NO. 6

HAZARDOUS WASTE MANAGEMENT SYSTEM: GENERAL; STANDARDS APPLICABLE TO OWNERS AND OPERATORS OF HAZARDOUS WASTE TREATMENT, STORAGE, AND DISPOSAL FACILITIES; AND HAZARDOUS WASTE PERMIT PROGRAM (40 CFR 260, 264, and 122)

Permitting of Land Disposal Facilities: Information Requirements for Permitting Discharges

This document (ms. 1941.39) provides background information on EPA's proposed regulations for land disposal of hazardous waste

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I. INTRODUCTION

Owners and operators of hazardous waste management facilities who are seeking a permit for a land disposal facility are required by the regulations to submit substantial amounts of information to allow the permit issuing authority to perform a realistic evaluation of the potential for the facility to cause adverse effects to human health and the environment.

It is expected that most of this information will be submitted in report form supplemented by appropiate drawings and basic data. The owner or operator (or their authorized agents) will be expected to draw analytical conclusions on the expected performance of the facility to support the application.

The basic informational requirements are set forth in §122.25. Paragraphs (c), (d), (e), (f), (g) and (h) describe those requirements which are specific to land disposal facilities. Paragraphs (a) and (b) set forth the informational requirements for all hazardous waste management facilities and storage and treatment facilities respectively certain of which are also applicable to land disposal facilities. The applicable requirements of paragraphs (a) and (b) were promulgated on 12 January 1981 at 46 FR 2889.

The information required in paragraphs (c), (d), (e), (f), (g), and (h) includes specific technical design data and generic information based on the types and amounts of waste to be disposed of and the specific geologic, hydrologic, and climatologic setting in which the disposal will occur. These facility specific data must then be analyzed to predict how the waste will act within the land disposal facility and with the environment.

Except in the case of existing facilities where much of the required information can be based on direct measurements, the informational requirements must be fulfilled by techniques which require skilled analysis of available hard data to hypothesize the expected results within acceptable ranges of real error. This potential for imprecision in analysis is provided for in the regulation by requiring both a best estimate of the expected results and a commitment on the part of the permit applicant which will establish the error limits within which the facility must perform. The monitoring requirements discussed in "Background Document No. 8 - Ground-water and Air Emission Monitoring" establish the means by which such best estimates of performance and the performance limits will be periodically reviewed during the operating life of the facility based on monitoring data to ensure compliance and improve definition.

I. NEED FOR REGULATION

A. Potential for Environmental Damage

EPA files contain many examples of environmental damage from improper land disposal of hazardous waste. Although damage to ground water is the most common occurrence, improper land disposal has resulted in surface water and air pollution as well. The following discussion describes reported incidents involving the contamination of all these media as well as public health damage that has occurred.

An EPA ground-water report, entitled "The Prevalence of Subsurface Migration of Hazardous Chemical Substances At Selected Industrial Waste Disposal Sites", investigated the likelihood of ground water contamination at hazardous waste land disposal sites. In this study, ground waters at 50 land disposal sites which received large quantities of industrial waste were sampled and analyzed. The sites selected were all located East of the Mississippi River, were representative of typical industrial land disposal facilities, and were situated in a wide variety of geologic environments. No previous contamination of ground water with hazardous substances had been reported at these facilities before sampling, and waste disposal has been in progress for a minimum of 3 years. At 43 of the 50 sites migration of one or more hazardous constituents was detected in the ground water. Twelve potentially hazardous inorganic constituents were detected in ground waters above background concentrations. The five most frequently occurring were selenium, barium, cyanide, copper, and nickel in that order. Organic substances that were identified in the ground water included PCBs, chlorinated phenols, benzene and derivitives, and organic solvents.

At 26 sites, potentially hazardous inorganic constituents in the ground-water samples from one or more of the monitoring wells exceeded the EPA drinking water limits. Of the potentially hazardous substances, selenium most frequently exceeded drinking water limits, followed by arsenic, chromium, and lead.

Conclusions drawn from the study are:

° Ground-water contamination at industrial land disposal sites is a common occurrence.

° Hazardous substances from industrial waste land disposal sites are capable of migrating into and with ground water.

° Few hydrogeologic environments are suitable for land disposal of hazardous waste without some risk of ground-water contamination.

° Continued development of programs for monitoring industrial waste land disposal sites is necessary to determine impact on ground-water quality.

° Many old industrial waste disposal sites, both active and abandoned, are located in geologic environments where ground water is particularly susceptible to contamination.

° Many waste disposal sites are located where the underlying aquifer system can discharge hazardous substances to a surface-water body.

B. Actual Damage Incidents

Numerous incidents of damage which resulted from improper land disposal are contained within EPA files. Rather than listing the vast number of damage cases for all types of land disposal facilities in this section, the reader is referred to summaries of damage cases in companion background documents.

II. ANALYSIS OF STANDARDS

1. Specific technical information requirements for land disposal facilities - §122.25(c)

A. Proposed Regulation and Rationale

N/A

B. Summary of Comments

N/A

C. Discussion

The purpose of §122.25(c) is to ensure that the permit issuing authority is provided with the information needed to determine that the proposed hazardous waste land disposal facility will comply with the applicable technical requirements of Part 264, Subparts K, L, M, N, R, and S. Much, if not all, of this information would routinely be recorded and analyzed by the owner or operator (or their authorized agents) independent of the requirements for submittal. Similar informational requirements have already been promulgated for owners and operators of hazardous waste treatment and storage facilties under §122.25(b).

The Agency does not believe that the requirements of §125.25(c) place any unnecessary burden on the owners or operators of hazardous waste disposal facilities. These requirements are organized so that an owner or operator only needs to submit information that pertains to his type of operation thus minimizing unnecessary expenditures of time and money.

Paragraphs (1) and (2) of §122.25(c) address the information requirements for surface impoundments and waste piles, respectively. The owners or operators of these facilities must submit information identical to that required under §122.25(b)(3) and (4) for surface impoundments and waste piles designed to treat or store hazardous wastes. No additional information is required in §122.25(c) for surface impoundments and waste piles designed for disposal of hazardous wastes, and in many cases the technical informational requirements are reduced since leachate collection, detection, and removal systems and secondary liners are not required.

The required technical information for land treatment, landfills, underground injection, and seepage facilities in §§122.25(c)(3), (4), (5), and (6) respectively are consistent with the types of information required for piles and surface impoundments under §§122.25(c)(1) and (2). Since land treatment, landfills, underground injection, and seepage facilities are not among the types of facilities listed as land disposal facilities in §264.19 which may also be used as storage and treatment facilities, they are not covered under §122.25(b). However, since the technical requirements for seepage facilities are based on similar requirements for surface impoundments, the requirements of §122.25(3) are referenced. As in §122.25(b), the informational requirements in §122.25(c) are limited to those needed to verify compliance with the design and operating requirements of Part 264, Subparts M, N, R, and S.

It should be noted that there were two codification errors in the regulation as printed at 45 FR 11172. In §122.25(c)(1), the proper reference is to §122.25(b)(3); and in §122.25(c)(2), the proper reference is to §122.25(b)(4). These errors are corrected in the following section.

D. Regulatory Language

In §122.25, paragraphs (c) through (h) are added as follows:

§122.25 Contents of Part B.

* * * * *

(c) Specific information requirements. The following additional information, based on the technical requirements of Subparts K, L, M, N, R, and S (generic requirements for all land disposal facilities are covered in paragraph (d) of this section), is required from owners or operators of specific types of HWM facilities that are used or to be used for land disposal:

(1) For all facilities that use surface impoundments for reasons other than solely for storage or storage and treatment, except as otherwise provided in §264.220, all of the applicable information requirements in §122.25(b)(3).

(2) For all facilities that use waste piles for reasons other than solely for storage or storage and treatment, except as otherwise provided in §264.250, all of the applicable information requirements in §122.25(b)(4).

(3) For all land treatment facilities, except as otherwise provided in §264.270, the owner or operator must submit detailed plans and specifications, and data which must collectively include the information itemized in paragraphs (i) through (iv). For new facilities, the plans and specifications must be in sufficient detail to provide complete information to a contractor hired to build the facility even if the owner or operator intends to construct the facility without hiring a contractor. For existing facilities, comparable detail must be provided, but the form of presentation need not assume contractor construction except to the extent that the facility will be modified.

(i) Detailed design drawings and specifications of the run-off collection structures required in §264.272.

(ii) The unsaturated zone monitoring plan as required in §264.278, including the rationale used in developing the plan and a detailed map of the facility showing the location and depth of the soil-pore water sampling devices.

(iii) Detailed descriptions of any inspection, testing, and recordkeeping procedures needed to comply with §264.279.

(iv) A description of the operating procedures including any plans or equipment that will ensure compliance with §§264.281 and 264.282.

(4) For landfill facilities, except as otherwise provided in §264.300, the owner or operator must submit detailed plans and specifications accompanied by an engineering report which must collectively include the information itemized in paragraphs (i) through (x). For new facilities, the plans and specifications must be in sufficient detail to provide complete information to a contractor hired to build the facility even if the owner or operator intends to construct the facility without hiring a contractor. For existing facilities, comparable detail must be provided, but the form of presentation need not assume contractor construction except to the extent that the facility will be modified.

(i) Detailed design drawings and specifications of the of the leachate monitoring system required in §264.301(a).

(ii) Detailed design drawings and specifications of any liner(s) and liner base(s) present at the facility and the installation procedures used to comply with §264.301(b).

(iii) Detailed design drawings and specifications of any leachate collection and removal system present at the facility demonstrating compliance with the requirements in §264.301(c).

(iv) Detailed plans and specifications and basis of design of any structures needed to comply with the general operating requirements in §264.302.

(v) Detailed descriptions of any inspection, testing, and recordkeeping procedures needed to comply with §264.306.

(vi) Detailed design drawings and specifications of the final cover required in §264.310(a).

(vii) Detailed descriptions of all maintenance, testing and inspection procedures to be used at the facility during the closure and post-closure care period as needed to satisfy the requirements of §264.310(b) and (c).

(viii) A map(s) which satisfies the requirements of §264.309(a) and (b). All existing facilities must submit map(s) showing the approximate location of each hazardous waste type within each cell for all wastes disposed of during the interim status period.

(ix) A description of the operating procedures including any plans or equipment that will ensure compliance with §§264.312, 264.313, 264.314 and 264.315.

(x) Detailed design drawing(s) of the landfill and surrounding geology showing the dimensions and depth of the uppermost aquifer beneath the facility.

(5) For underground injection facilities, except as otherwise provided in §264.430, the owner or operator must submit detailed plans and specifications accompanied by an engineering report which must collectively include the information itemized in paragraph (i) through (v). For new facilities, the plans and specifications must be in sufficient detail to provide complete information to a contractor hired to build the facility even if the owner or operator intends to construct the facility without hiring a contractor. For existing facilities, comparable detail must be provided, but the form of presentation need not assume contractor construction except to the extent that the facility will be modified.

(i) A statement of the maximum pressure to be applied to the well head and basis (calculations) of establishment.

(ii) A statement of the annular pressure to be maintained and basis (calculations) of establishment.

(iii) An analysis of the well construction material selection including casing, cementing, tubing and packer materials.

(iv) A description of the operating procedures to comply with §264.432.

(v) A description and justification of well plugging techniques to be utilized at closure.

(6) For seepage facilities, except as §264.460 provides otherwise, all applicable information requirements in §122.25(b)(3).

2. Informational requirements for permitting discharges from land disposal facilities - §122.25(d)

A. Proposed Regulations and Rationale

In the 8 October 1980 supplemental notice of proposed rulemaking, the Agency discussed the approach it intended to use to regulate hazardous waste land disposal facilities. The "ground water protection standard" was described under a heading "Presumption against degradation" and in what was perhaps an unfortunate choice of language it was characterized as a "nondegradation standard". As is discussed in Background Document No. 7 - Ground Water Protection Standard, commenters tended to apply their own meaning to the term "nondegradation" rather than the meaning intended by the Agency. Many commenters ignored the most important feature of the standard; the direct association with subsequent use.

The information requirements, which are the subject of discussion in this section, were described under the heading "Permissible demonstrations that limited degradation will not threaten public health or the environment". The applicable informational requirements described in the notice required a permit applicant to provide information for each of five main subject areas as follows:

- A description of the wastes (both qualitative and quantitative) to be disposed of in the facility.
- A description of discharges (including leachate and gas migration) from the facility.
- A description of the hydrogeologic characteristics of the unsaturated zone and of the migration of the discharges in the unsaturated zone.
- A description of the hydrogeologic characteristics of the saturated zone and of the migration of the discharges in the saturated zone.
- A description of all discharges to the land surface, into surface waters, and all withdrawals of ground water that will be mixed with discharges from the disposal facility.

B. Summary of Comments

Commenters expressed several major concerns regarding "EPA's Intended Approach" in the 8 October 1980 notice pertaining to the informational requirements and demonstrations required of the permit applicant. First, the commenters contended that the required information and demonstrations were extensive, extremely costly and beyond the reasonable capacity of most permit applicants to provide.

Secondly, they felt that not all of the information and demonstrations described were needed in many cases (e.g., land disposal facilities underlain by deep, tight clay soils and located over deep, non-usable ground water aquifers). Thirdly, they claimed that some of the demonstrations (e.g., prediction of the human health risks posed by contaminants that migrate to points of water use) were far beyond the capabilities of permit applicants if not the state of the art. Finally, they argued that some of the requirements (e.g., health and risk assessments) placed burdens on the permit applicants that properly should rest with EPA or other government agencies.

C. Discussion

EPA agrees that the information and demonstration requirements may be quite costly and burdensome for some permit applicants and, for others, will not be insignificant. Given the long-term hazard potential of land disposal of hazardous wastes documented in the damage cases, however, it believes that such requirements are essential to making sound environmental judgments about these disposal activities. The costs and efforts of meeting these requirements are justified costs of doing business and of having the privilege of depositing hazardous constituents in or on the land where they might adversely affect people's health and welfare for many decades.

Furthermore, EPA believes that proper siting of land disposal facilities, proper pre-treatment of certain hazadous wastes and tailored design of facilities for different types of wastes will reduce the information and demonstration requirements and, thereby, will alleviate their costs and burdens. For example, locating facilities in areas underlain with deep ground waters or non-usable ground waters or underlain with deep formations of low permeability clay soils will enable the permit applicant to readily demonstrate that contaminants will not migrate to points of water use, thus lessening the requirements that otherwise would apply. Pre-treating hazardous wastes so that they do not contain the more toxic or carcinogenic hazardous constituents also will lessen these requirements. Likewise, tailoring the disposal facility to the types of wastes disposed so that, for example, a reduction in the solubilization of hazardous constituents will occur could lessen the requirements. The Agency has tried to provide, in the standards proposed, provisions that require more or less informaton and demonstration based on site-specific, waste-specific conditions.

For those permit applicants that insist on locating a land disposal facility over a shallow, high quality, highly used ground water aquifer or insist on placing highly toxic wastes in a land disposal facility without pre-treatment or insist on otherwise locating, designing and operating a system that is capable of discharging contaminants that will migrate to and affect water uses, it will be both difficult and expensive to assemble the information and provide the demonstrations required for permitting decisions. However, in EPA's view, these costs and burdens are necessary to assure that the facility will not cause unacceptable environmental degradation.

The Agency recognizes that these assessments will require permit applicants to gather and to submit considerable detailed information and (in some cases) to perform difficult and complex demonstrations. It also recognizes that the required information and demonstrations will be difficult and time consuming to review by EPA and State permitting officials and very likely will require more time in processing and issuing permits than might otherwise be required if design and operating standards or containment standards were employed. However, EPA concludes that these consequences must be accepted in order to provide for full consideration of the serious implications that the facility might have for the public's health and welfare for decades to come.

The Agency also realizes that the extensive information and demonstration requirements of the proposed regulations will (in some cases) be sufficiently great to deter land disposal permit applications for many locations, for some wastes and from some persons. As such, the proposed rule, if promulgated, will probably reduce the number of land disposal facilities, significantly limit the location of these facilities, limit the types of hazardous wastes placed in these facilities, promote the use of alternative methods of managing hazardous wastes (e.g., incineration, treatment, recycling) and preclude potential permit applicants who lack the resources or the technical capability to meet the information and demonstration requirements. In the Agency's view, these are not undesirable results. Because it frequently poses long-term hazards to human health and the environment, EPA views land disposal as the least desirable method of hazardous waste management and believes it should be used only in those situations where, because of the location of the site, nature of the waste and adequacy of the management technologies and operating practices used, it can be carried out in a manner which will assure long-term protection of human health and the environment. Clearly, the permit application requirements will create economic and feasibility constraints that will limit land disposal practices. The Agency, however, does not believe these standards and requirements will preclude land disposal as a necessary hazardous waste management practice. It contends that there are suitable land disposal sites, adequate land disposal facility designs and practices and competent persons and firms to operate land disposal facilities necessary to manage hazardous wastes that cannot be handled by other alternatives.

Finally, the Agency recognizes that the techniques for making the hydrogeological investigations and other studies necessary to meet the information and demonstration requirements of the proposed regulations are not fully developed and need to be improved and extended. It also recognizes that the technical expertise of undertaking these investigations and studies is limited. It believes, however, that the techniques and expertise exist to perform, in some degree, each of the investigatory tasks that would be required. Certainly, advancements in the state of the art and capabilities, which will result from the implementation of the proposed requirements, will improve performance in the future. EPA believes that the requirements proposed will encourage such advancements. Evaluation of the state of the art is included in the technical discussions which follow.

In Section III of the the Preamble, there is a discussion which concentrates almost exclusively on the problems associated with those types of land disposal facilities which are designed and operated with the primary objective of long term facility containment of hazardous wastes. The discussion describes the essence of the problems faced in the regulation of such forms of land disposal of hazardous waste as the inevitable long-term potential for the wastes or their hazardous constituents to leak out of the facility. In the discussion it is concluded that "If it were technically and institutionally possible to contain wastes and their constituents in land disposal facilities forever or until degradation mechanisms rendered them non-hazardous, then the problem of regulating such (types of) land disposal would be comparatively simple and straight forward. It would entail development of reasonably specific (but flexible) design and operating standards or, alternatively, containment performance standards specifying total containment of hazardous wastes and their constituents within the land disposal facility forever or until degradation mechanisms rendered them non-hazardous, as the case may be. Unfortunately, at the present time, it is not technologically and institutionally possible to contain wastes and constituents forever or for the long time periods that may be necessary to allow adequate degradation to be achieved. Moreover, if degradation of the hazardousness of waste does, in fact, occur, current state-of-knowledge does not know what the degradation periods are for most, if not all, hazardous wastes and, therefore, does not know what containment time periods to specify.

Consequently, the regulation of hazardous waste land disposal must proceed from the assumption that migration of hazardous wastes and their constituents and by-products from a land disposal facility will inevitably occur."

Because of this inevitability of leakage from land disposal facilities which are designed to achieve facility containment, and especially in view of the fact that most existing land disposal facilities have not been designed with this objective, it is necessary that the discharges which will occur from land disposal facilities be assessed with respect to potential effects on human health and the environment. These assessments must be performed for each facility on a waste specific and site specific basis. The specific informational requirements of §122.25(d) which provides a basic framework for the assessments are discussed in detail below. Integrated into the discussion are certain provisions intended to to provide maximum flexibility in implementing the informational requirements, by allowing varying levels of precision to be employed. Section 122.25(e) outlines the framework for recognizing major differences in the need for information, in site and waste specific circumstances, and the inadequacies in the state of the art which necessitate allowing some flexibility in the degree of precision required to comply with informational requirements. Therefore, this section is intended to limit unnecessary informational requirements and ease the regulatory burden wherever possible without jeopardizing the objective of the regulatory program; assuring that an adequate assessment of potential health and environmental effects is achieved.

(1) General

The informational requirements for permitting discharges from land disposal facilities include a determination and assessment of the extent of transport of contaminants discharged or leached as a liquid or emitted as a gas from hazardous waste land disposal facilities. The requirement is further detailed to identify the specific wastes and quantities placed in any operational unit, §122.25(d)(1); the release of liquid and gaseous contaminants from the waste deposit, §122.25(d)(2); the rates and extent of dispersion and transport in earth materials above the zone of saturation, §122.25(d)(3); the extent and rate of the leachate carried contamiant transport in the zone of saturation, §122.25(d)(4); and a description of the rate and location of leachate carried contaminant discharge from the zone of saturation, §122.25(d)(5). These informational requirements are intended to track the potential routes of contaminant transmission from the hazardous waste disposal facility and to enable the assessment of the severity of the potential effects.

The need for the requested information and description of existing techniques to forecast performance is discussed subsequently. The specific information of waste types and quantities is a design/operational controlled variable which can be defined by the applicant and may ultimately represent a limit to growth of the operational unit or even the facility. Further discussion of this requirement is not provided. Description of the rates at which gas and/or leachate contaminants are emitted from the operational unit or facility are discussed separately. The emission of leachate contaminants is described from two perspectives: (1) volumetric production, and (2) the prediction of waste leachate composition (including both the waste's constituents and decomposition products). Contaminant transport above the zone of saturation and within the zone of saturation are each discussed separately.

(2) Predicting Leachate Volume

The leaching process generally represents the principal mode of transmission of contaminants from a waste deposit to the environment for landfills and surface impoundments. Of course, for seepage facilities where the objective of the design is to leach liquids from the waste, it is the essential consideration. Volatilization and release or dispersion as a gas is a secondary, although important, factor for most landfilled wastes. For surface impoundments, land treatment facilities, and seepage facilities, volatilization is major consideration. With respect to liquid discharges, it is important, therefore, for any hazardous waste disposal facility, including landfills and surface impoundments, that an assessment be made regarding the potential for leaching of contaminants under the specific site conditions (environmental, designed, and operational) which the waste may be exposed to. The principal and initial step in such an analysis is the forecasting or estimation of volumetric discharge or leachate production.

The volumetric discharge from surface impoundments, seepage facilities, and injection wells can be determined directly during the active life of the facility. However, the specific needs for quantitative, time-related information are many for landfills, land treatment facilities, and for surface impoundments and seepage facilities which are closed with waste left in place. Certainly the most important would be a determination of whether site conditions can be expected to yield leachate. Resolution of that question, however, requires careful assessment of a variety of factors and site conditions. Important considerations include: rainfall, runoff, evaporation, transpiration, waste dewatering, and specific design controls. These factors need to be assessed with regard to their effect on volumetric leachate production during operational phases as well as post-closure phases of the landfill facility. Typical results of such an assessment at traditional landfills are that leachate is produced and the rate of production varies substantially throughout the year in response to climatic and hydrologic conditions.

Knowledge of leachate production rates is particularly important in determining and forecasting leachate composition or quality. The quality of leachate is typically a time related function; although time itself is seldom the principal control variable. More frequently, leachate volume or the quantity of eluant which the waste has been exposed to is the principal control variable. When the leachate production is low, one may therefore expect a prolonged period of contaminant releases and transport as compared to a relatively short period when leachate production is high. An illustrative example is the comparative results of municipal solid waste leaching where a moderate leaching rate yields concentrations of contaminants significantly greater than a high leaching rate over the same period of time (Figure 1). Similarly, the mass of contaminants released to the environment more rapidly approaches

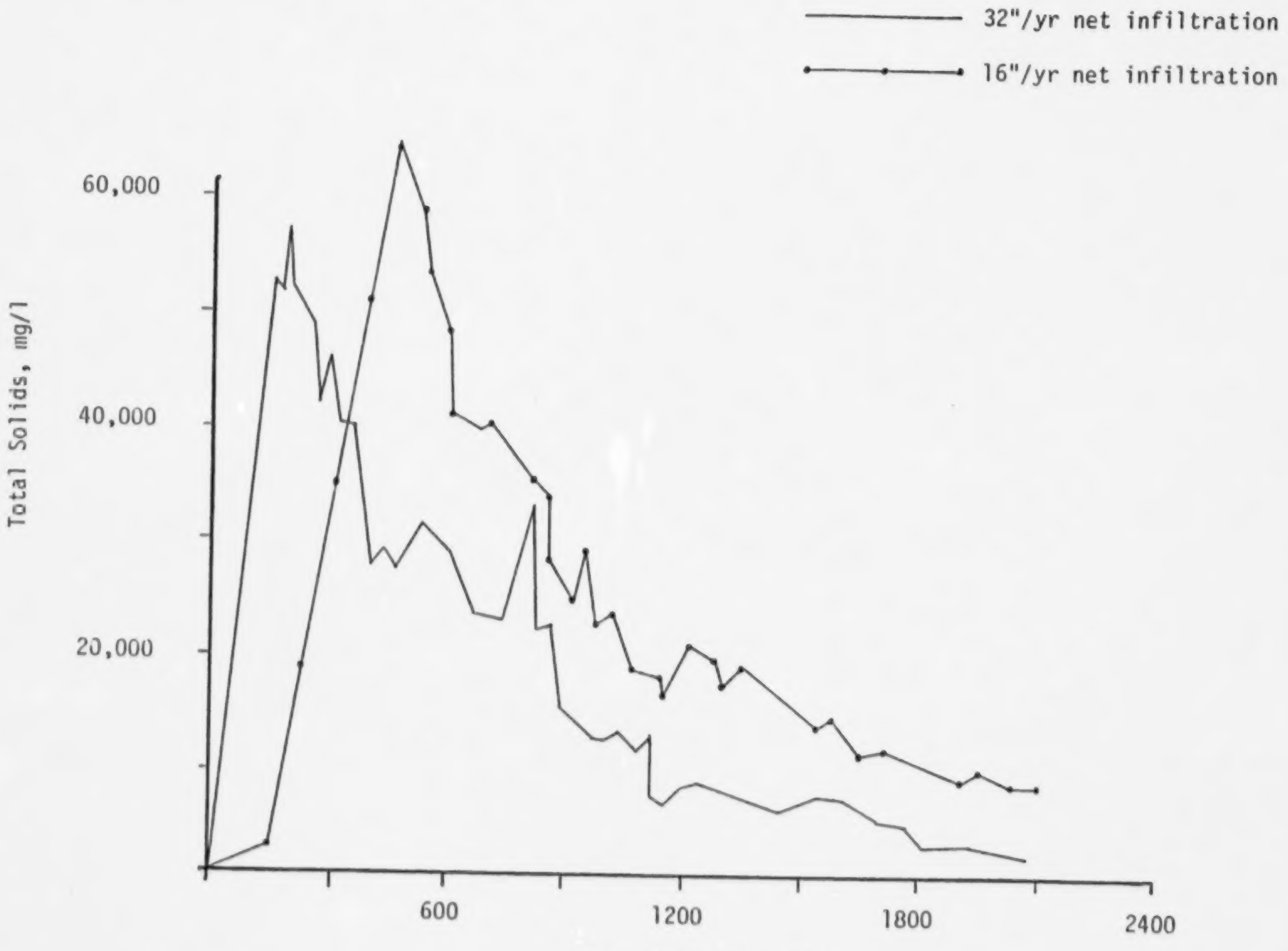

Figure 1. Dependence of Contaminant Concentration on Extent of Leaching

its unique asymptotic level for the high leaching rate as compared to the low leaching rate (Figure 2). Thus, an understanding of the leachate production rate is essential in describing and forecasting leachate composition and ultimately, the length of time over which the leachate may be determined to represent a potential problem.

The time over which post-closure care should be maintained is greatly influenced by volumetric leachate production. Requirements, both technical and economic, of the post-closure care period are therefore integrally related to the rate of leaching. An obvious element of a typical post-closure care plan would be the costs of operating leachate control systems such as collection and treatment facilities.

Determination of the adequacy of leachate management options chosen at any particular site rely in part on the volumetric leachate production. The technical and economic feasibility of options such as trucking collected leachate to off-site hazardous waste facilities are particularly dependent on the volume of leachate being managed. On-site collection and treatment facilities are likewise sensitive to volumetric loadings.

Subsequent use of mass emission determinations are also dependent on the volumetric production. Certainly, the assessment of risks associated with certain constituents of hazardous waste is dependent on their concentration during exposure, while that concentration is in turn dependent on volumetric production. Likewise, the extent of contaminant transport and dispersion is in part dependent on the rate of leachate production.

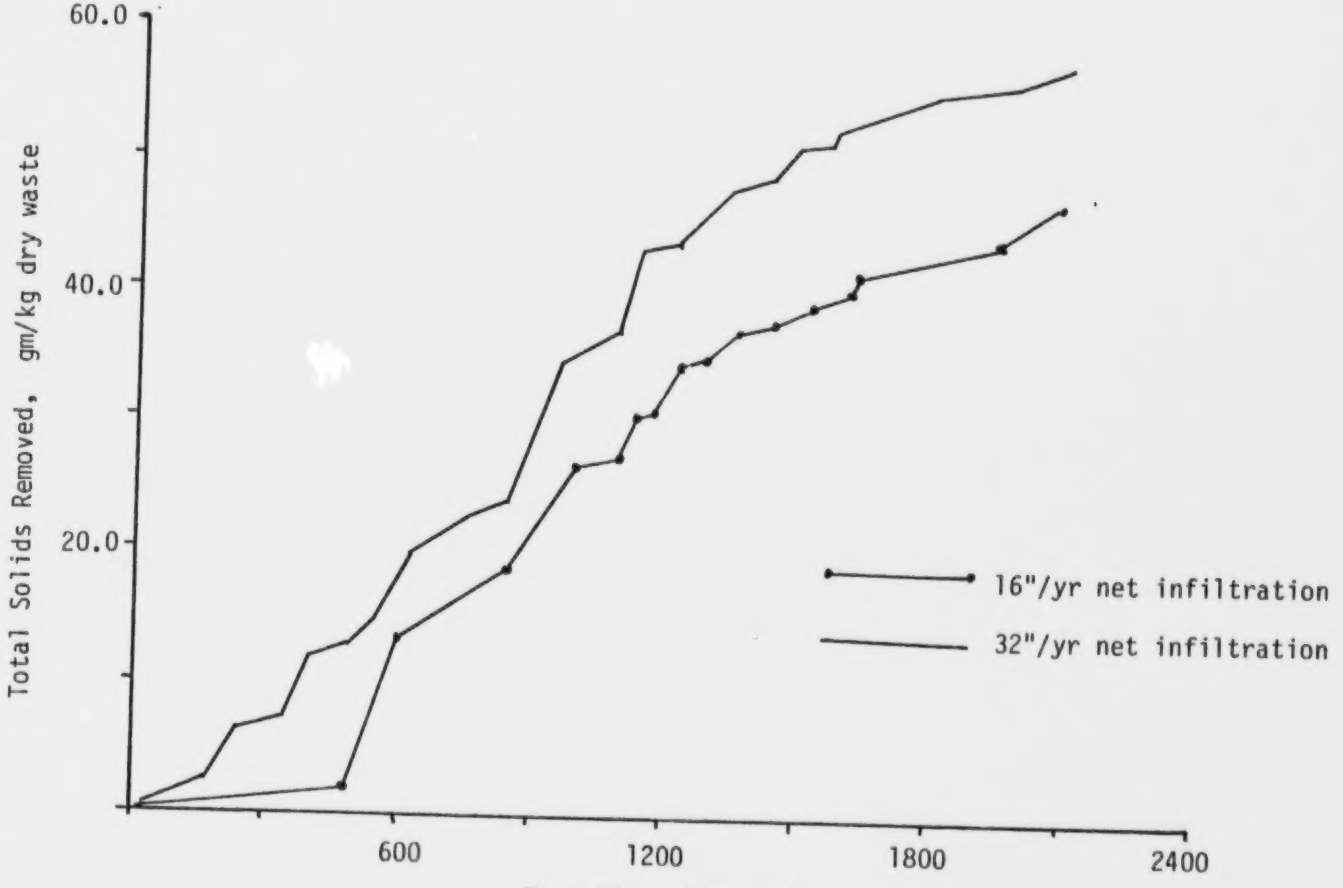

Figure 2. Dependence of Mass Removal on the Extent of Leaching

The need to determine volumetric discharge or leachate production is inherent in the technical design and evaluation of any hazardous waste land disposal facility. The information is necessary for assessments of related risks to human health and the environment posed by contaminants in the discharge or leachate. The sizing and design of any leachate management system is dependent on the volumetric production rate. The need for leachate management systems is irrelevant in the absence of leachate. Consequently, a critical element in the evaluation of a hazardous waste land disposal facility must include an assessment of the volumetric production of discharge or leachate.

(a) Elements of Analysis

The volumetric production of leachate has been the subject of several studies, particularly with respect to municipal solid waste landfills. The forecast of leachate production (usually with the water balance method) in such facilities has typically been analyzed from the perspective of an idealized landfill in a closed or post-closure mode of operation. This approach has been taken because municipal solid waste has a large moisture absorptive capacity--in the order of 1 to 2 times its own dry weight. Large quantities of wastes are typically disposed of daily, thereby, providing a large capacity for absorpton of incident rainfall during the uncovered operational phase. However, not all hazardous wastes have a water absorption capacity; in fact, many wastes such as those managed at surface impoundments, land treatment, and seepage facilities contain free liquids. Consequently, the forecasting of leachate production from hazardous waste facilities must include analysis of the operational phase as well as the post-closure phase.

Specific sources of water or other solvents include rainfall, run-on, irrigation of cover soils, ground water, perched water, flood water, water derived from waste composition, alcohols and other liquids resulting from unique decomposition processes, and water and other liquids contained within the waste originally placed in the facility. Proper land disposal practices and other parts of the hazardous waste regulations (See §264.300, Subpart N-Landfills) eliminate or greatly reduce the likelihood of water contribution from flooding, run-on or ground water. Earth materials conducive to perched water tables can be avoided, but may have to be dealt with in an otherwise desirable site. Irrigation water used for establishment and maintenance of the cover system is a manageable source which when properly applied should not represent a significant source of water. It should, however, be explicitly assessed. Similarly, water derived from the decomposition of solid waste has typically been determined to represent a very small, negligible source; it should also be explicitly assessed for the specific combination of wastes to be managed in the facility. The potential for other liquids resulting from decomposition, such as alcohols and aldehydes, should be assessed. Generally, water or other liquids derived from the decomposition of wastes, such as described by Charlie et al. (6) for certain papermill sludges, represents a finite volume of liquids. Alternatively, rainfall, perched water and irrigation water represent a continuous, although sometimes intermittent, source of liquid, and consequently, the most important source with respect to soluble, slowly decomposing (if at all) hazardous wastes. Such a prioritization is generally valid, however, only for volumetric forecasting. Water and other liquids resulting from the decomposition and slow dewatering of high moisture wastes may represent the most significant source of contaminants. Wigh and Brunner (40) have observed that the composition of initial leachings, particularly those with a moisture absorption capacity comparable to that of municipal solid waste, generally contain the largest concentrations of contaminants.

Other potential sources of liquid which may contribute to leachate production are management practices. Such techniques as proposed by Pohland for municipal solid waste attempt to accelerate decomposition by enhancement of leaching. Similar practices, not necessarily intended to enhance biological decomposition, based on the elution of hazardous materials for subsequent concentration and management, may significantly influence leachate production forecasts.

There are several means or mechanisms which function as sinks to remove water (or other liquids) from land disposed wastes. These include: incorporation into biological cell mass or chemical compounds, absorption to the waste, evaporation, transpiration, collection in a leachate management system underlying the waste, and seepage out of the facility as migrating leachate. Incorporation of water into cell mass is at best a transitory sink for leachate. This biological sink may in fact be a net contributor of leachate as the cell mass decays. Incorporation into chemical compounds represents a limited sink which may not always be effective. The long-term utility of such a sink is minor with respect to the long-term quantity of water introduced to the facility by infiltration and represents a finite capacity specifically related to the waste and predominant to chemical reactions. The major sinks or discharges of leachate are: collection within the facility and discharge to surrounding soils and other geologic formations, and eventually seepage into the ground water, or migration as a surface discharge. Losses of liquids due to evaporation and transpiration act principally on infiltrating rainwater and irrigation water for the final cover system. Many factors influence the rate of evaporation and transpiration. Some of the more important factors are: relative humidity, solar radiation, cloud cover, temperature, wind speed, plant coverage, soil type, soil depth, and root penetration. Evaporation may also be an effective means of reducing quantities of moisture within the waste itself, particularly in a biologically active waste where net gas production flushes moisture laden gases out of the deposit.

A particularly important element of leachate forecasting is the sensitivity of the analysis to site specific conditions, either naturally occurring or purposely imparted through design and operation. Rainfall and evapotranspiration are especially localized, natural occurring phenomena. Surface runoff can be controlled to a large extent by slope and length of run of cover materials which can be specified in facility design. Other design alternatives are vegetation type, soil types, and soil depths. Operating procedures can be instituted to minimize leachate production by careful phasing and scheduling of the filling operation to rapidly achieve final grade and placement of the cover material.

A summary of the sources and discharges (sinks) of land disposal facility liquids is given in Table I. The major elements can be generally related by a simple water balance analysis:

Liquid in = Liquid out

Rainfall + Irrigation = Evapo-Transpiration + Runoff + Collected Leachate + Migrating Leachate

The primary element of concern to the hazardous waste land disposal facility permitting process is the last term: Migrating Leachate.

TABLE 1

SOURCES AND SINKS OF LIQUIDS AT LAND DISPOSAL FACILITIES

	One time or transient	Continuous	Poor Practices
IN: SOURCES	Initial Waste Moisture	Rainfall	Run-on
	Waste Decomposition	Irrigation	Flooding
	Waste Dewatering		Groundwater
OUT: SINKS	Biological Incorporation	Evaporation	
	Chemical Incorporation	Transpiration	
		Collection System Drainage	
		Leaching from Facility	
		Runoff	

The forecasting of leachate production is not a simple task. Many factors need to be included during any assessment. These factors include: the sources and discharges of waste contaminated or originating liquids, facility operational status, specific facility location in the environment, and design and operational aspects of the facility. Additionally, many of these factors are not controllable, nor precisely predictable, being a result of natural phenomena such as rainfall. Nevertheless, relationships and rather limited ranges of variation do exist for these factors. Consequently, estimates of leachate production are feasible. The utility and accuracy of those estimates, however, must be kept in perspective with the accuracy and predictability of the information used to produce the estimate. A special requirement of any leachate forecasting procedure imposed by the regulations is the flexibility to produce reasonably expected production rates and also worst case or maximum rates.

(b) Methods of forecasting

The prediction of leachate production is based on traditional scientific and engineering approaches used in water resources and agricultural management, and more recently, on computer aided approaches. Early applications of water balance solutions to the land disposal of solid wastes were based on the work by Thornthwaite. Remson, et al. (37) reported on the adaption of Thornthwaite's Water Balance tables to solid waste landfills with the aid of digital computers. The State of California (5) suggested the use of U.S. Bureau of Land Management (USBLM) methods of estimating infiltration using curves which estimate peak discharge rates for small watersheds.

A series of curves are provided by the U.S. Department of Agriculture Soil Conservation Service (USDA/SCS) which do provide a wide range of storm distributions, slopes and rainfall. Fenn, et al. (12) adapted the work of Thornthwaite and Remson, et al. (28) in a report entitled: Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites. Noble (25) combined Thornthwaite's work with the USDA/SCS curves.

More recently, Perrier and Gibson (27) adapted another USDA or agricultural based tool: Chemicals Runoff and Erosion from Agricultural Management Systems (CREAMS) for landfill design and evaluation purposes. This interactive computer aided tool yields daily estimates of infiltration, runoff and evapotranspiration. Straub (33, 34) developed a series of models to estimate leachate volumetric production and quality from municipal solid waste.

The U.S. Department of Agriculture (USDA) has performed field validations of the CREAMS model for estimating the volumetric production of leachate. The model, USDA/CREAMS (39), has been used to provide extensive validation for crop and rangeland plots. Although it has not yet been applied to land disposal facilities, the background data can, nonetheless, be used for extrapolation and validation information for land disposal sites until such time that actual data exists.

In general, most existing forecasting techniques have estimated evaporation-transpiration losses using tabulated observations and the potential evaporation-transpiration concept offered by Thornthwaite and applied by Remson and Feen. Alternatively, the Available Water Capacity (AWC) algorithm is used by USDA/CREAMS, Perrier and Gibson in their Hydrologic Simulation on Solid Waste Disposal Sites (HSSWDS), and by Straub. The former technique approach tends to approximate events and conditions by use of averages, while the latter, depending on the need, can more closely approach the simulation of discrete events. A limitation of the Thornthwaite tables is that they represent long-term averages on a monthly frequency. The AWC algorithm can be used on a more frequent basis. The need to consider extreme conditions during the design and evaluation of the hazardous waste disposal facilities indicates a preference towards the use of the AWC algorithm which is much more sensitive to site specific managerial and locational constraints than the Thornthwaite tables, particularly where the need for accurate, frequent predictions is necessary.

Runoff, another major part of the water balance assessment, can be estimated using the Rational Formula - Fenn, et al, (12) and Remson, et al. (28) and SCS curves (27). These methods are empirical and require consideration of the wetting history of a site in order to select the proper coefficients or curves. The USDA/SCS curves, provide limited consideration of this aspect by identifying a number of storm types and intensities.

Integration of the SCS curves with the daily precipitation and evapotranspiration analytical capacity of the USDA/CREAMS model offers a particularly attractive capability of providing storm by storm analysis when conditions warrant. Alternatively, this technique can be used to provide general summaries in less critical situations. The simplicity and relative accuracy of the Water Balance approach using Thornthwaite's tables and either SCS curves or the Rational Formula should not be overlooked. Dass, et al. (19) and Lutton (18) have indicated a good correlation between estimates made according to Fenn and actual field data. They also indicate that the most critical factor in the analysis is the selection of the surface runoff coefficient.

Although, previously discussed procedures do not incorporate analysis of the efficiency of leachate collection systems, a procedure to estimate liner performance efficiency has been described by Wong using traditional Darcian flow analysis of differential permeability. Wong's (41) solutions considered the length of run in leachate collection systems, the steepness of slope, permeabilies of drainage and barrier soils, and incident leachate production rates. It was clear that under conditions of: low slope, long run, small permeability differentials, and small, but steady, leachate flow rates, that efficiency of clay liners may be much less than popularly assumed. Collection efficiencies of less than 50 percent can readily be estimated for common practices.

Subsequent work by Moore (24) has led to development of an evaluation procedure which routes water percolating from the cover system through the waste, across barrier systems (leachate liner and collection systems) and eventually into the native soils underlying and surrounding the facility. This procedure recognizes the potential for lateral (horizontal) flow in addition to vertical flow as differential permeabilities are encountered. The procedure also recognizes limitations of Darican flow theory when applied to the landfill situation. Results of this evaluation procedure can be utilized to assess the adequacy of the drainage layer in a

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leachate collection system, the adequacy of the differential permeability of such collection systems, and the steady state seepage rate. In addition, this procedure can provide estimates of the total retention time and the amount of liquids in the facility. The procedure was noticed in the Federal Register for public review and comment, as was the Hydrologic Simulation of Solid Waste Disposal Sites model (HSSWDS) developed by Perrier and Gibson.

(c) Summary

There exist several methods of estimating leachate production based on analyses of the major contributions and losses (sinks) for liquid: rainfall, runoff, evapotranspiration and net percolation or leachate. In addition, the efficiency of leachate collection systems can be determined. Although, no single procedure is currently available which also explicitly considers the generally minor water losses and gains attributed to waste decomposition and absorbtion, nonetheless, the available procedures can be adapted to reflect these minor amounts. In special cases where water losses and gains due to decomposition and absorbtion are anticipated to be significant, these processes can be analyzed separately.

(3) Leachate Composition

(a) Background

The discussion of leachate composition addressed here is not the composition of the liquids produced by the Extraction Procedure developed under RCRA section 3001. That liquid analysis is intended to simulate liquids which would be produced if the waste were disposed of in a municipal solid waste environment. Rather, the leachate analysis discussed here would be typified by that liquid originating from one or more hazardous wastes placed in a land disposal facility, particularly that liquid after it has left the wastes and yet before it had passed into undisturbed native soil at the facility. The leachate would be that liquid produced by a collection and removal system at a facility lined with a nearly impervious material.

Leachate composition includes not only information on the types and concentrations of materials present in the initial liquid that issues from the waste, but also information on any changes in the types and concentration as additional infiltrating liquid (e.g., rain) passes through the waste.

Information on leachate composition may be needed for a variety of purposes.

- predicting the effect of leachate releases on adjacent waters
- designing treatment systems for collected leachate
- determining the length of time after closing that the facility will have to be monitored and maintained.

(b) Discussion

(i) Previous work

Development of the Extraction Procedure for RCRA Section 3001 was the culmination of a number of studies (2, 5, 6, 8) that examined available leach tests and influences of test conditions on the leaching process. A large scale study with municipal solid waste and industrial waste (9) is underway as a basis for evaluating the extraction procedure. Several industries have worked on leach tests (1, 10, 11) to examine not only the potential for leaching from their wastes but also to develop a realistic estimate of the composition of the leachate which would be produced from their wastes (disposed of in the absence of other wastes). A laboratory study of several industrial wastes (7) developed batch procedures for predicting the composition of leachate from large-scale land disposal facilities. The leaching regions used in the various techniques range from aggressive (for estimating maximum release), to mild (for simulating mono-disposal under field conditions).

(ii) Alternatives

Applicants seeking to predict the composition of leachate may analyze leachate from a similar existing facility over a period of time or make use of present or past work with samples of the waste to predict composition of its leachate. In addition to the work described above there are several groups developing leaching tests (3, 4) and the announcement for a future ASTM Symposium (12) indicates that a number of private companies are actively developing leaching tests for use in managing waste disposal practices. Though work is somewhat limited, studies are being conducted on a variety of wastes under different conditions and present work does outline the: precautions to be taken, estimates of difficulties involved, and results to be expected. The task of making a prediction of leachate composition (assuming a sample of waste is available) should not require unreasonable efforts on the part of the applicant. Disposal facilities that include some control of the rate of release of leachate (such as a leachate collection and removal system) will generate data for adjusting the prediction soon after the facility is in operation.

(4) Predicting Gas Emissions

The following aspects are common to all evaluations of gaseous emissions from land disposal facilities.

- ° identify potential gases and vapors of interest and estimate quantities anticipated
- ° determine the most probable mode of transport (pressure or diffusion gradients) and estimate the extent of movement.

The most critical aspect of this evaluation is determining what types and quantities of gases and vapors can be anticipated.

It is obvious from the experience at Love Canal that an important mode of transport of hazardous wastes is by gaseous movement. Occupant exposure in dwellings near the waste was principally by volatilization of the various hazardous waste constituents either directly from the waste deposit or more probably, in this case, from leachate-contaminated ground water. Emission of explosive (methane) and toxic (hydrogen sulfides) gases from municipal solid waste has been a concern for many years; however, most assessments from such emissions were centered on release from the waste mass rather than the release from migrating leachate. The emission of gases from both the migrating leachate and the waste deposit are considered essential in evaluating potential risks posed by a hazardous waste facility.

(a) Identification of Gases

Gases of concern orginate from the waste itself or its decomposition products. Review of the waste composition should reveal information on the probability of gas emissions by direct volatilization. Compounds with high vapor pressures should be carefully considered; those with low vapor pressures may still require assessment depending on the hazard they present.

Shen and Tofflemire (31) reported that the compounds shown in Table 2 were detected in air near landfills. The quantities detected seemed small, but the PCB concentration was greater than recommended by NIOSH for a workroom environment (1.0 migrogram/cu.m) where exposure is typically based on an 8-hour work period. Equivalent ambient air levels would be expected to pose a greater risk. Note also that although vapor pressure is relatively small for PCB, there was a significant quantity found; this is indicative of the quantity of PCB disposed at the facility. Shen and Tofflemire also described some of the important factors influencing the rate of volatilization and showed how the unknown properties of a specific waste can be estimated using properties of similar compounds.

TABLE 2

COMPOUNDS FOUND IN AIR NEAR LANDFILLS*

	Vapor Pressure mm of Hg @ 20 C	Reported concentration micrograms/cu m
Benzene		270
Chlorobenzene		240
chloroform		24
Chlorotoluene		6700
PCB winter	.0001-.000001	0.05-3.0
summer	.001-.00001	up to 300
Tetrachloroethane		1140
Trichlorobenzene		74
Trichloroethane		73

*adapted from Shen and Tofflemire. (31)

The production of methane and carbon dioxide in hazardous waste disposal facilities should not be overlooked. These gases can be produced at rates high enough to create convective pressure gradients. The resulting flow of gas flushes smaller quantities of hazardous gases out of a landfill at a rate faster than those gases would have otherwise moved. In addition, the methane itself represents a potential hazard if it is not properly managed. There is extensive information in the literature on the composition and production rates and capacities of decomposing organic wastes.

(b) Release of Gases and Vapors

The release of gases from land disposal facilities can be viewed as: (1) dispersion through the soils underlying and surrounding the facility, (2) dispersion through the unsaturated zone in the vicinity of leachate contaminated soils, or (3) upward release from the waste itself. Special cases of the latter mode are presented by impounded liquids exposed to the air as with surface impoundments, underground seepage facilities, or intentional mixing of hazardous wastes with soil, as with land treatment facilities. Mixing with soil can greatly increase the surface area of the waste and thereby increase the flux of waste or vapor to the atmosphere.

The first two modes of dispersion are similar and comparable to that of methane moving from a municipal solid waste landfill (Subtitle D Facility). Several investigators have proposed models and equations to describe this flow.

Moore has described a number of models based on diffusive and convective flow (21,22,23). The choice of model is largely one of experience and anticipated rates of gas generation and confinement.

Design charts were developed to provide a simple tool for rough estimating and also as a planning tool. The design charts are derived from the basic equations and were produced as a result of finite element and finite difference solutions to the descriptive equations. The design charts were adapted for use in the Subtitle D Inventory. The various models were verified on a limited basis in the field at a landfill in Hopkins, Minnesota where methane was threatening nearby townhouses (23). There was a reasonably good correlation between the predicted concentrations and locations and the field data. Although the solutions were developed for estimating methane movement, the chemical species is a variable in the equations. Other compounds can, thereby, be readily incorporated into the model. Farquhar et al. (8) has also reported on a joint convective and diffusive flow modeling effort. Solution of the descriptive equations is by finite element techniques. The model has received limited validation in the field although it has been calibrated to improve its accuracy.

Anderson and Callinan (2) concluded that gas flow in municipal solid waste landfills was primarily the result of convection and therefore the basic rate equation would be described by Darcy's law. The convection theory was applied to a two-dimensional landfill analogue (electrical conducting paper) to predict movement patterns. Conversely, in a report to the California State Water Pollution Control Board, molecular diffusion was identified as the most effective transfer mechanism. Diffusivity of a porous medium was stated to be relatively independent of soil particle size. Dry clayey coils are not an effective gas control system.

Most recently, Findikakis and Leckie (13) have proposed an implicit one dimensional model for methane, carbon dioxide, and nitrogen gas flow. The model was successfully tested at several recently constructed field sites.

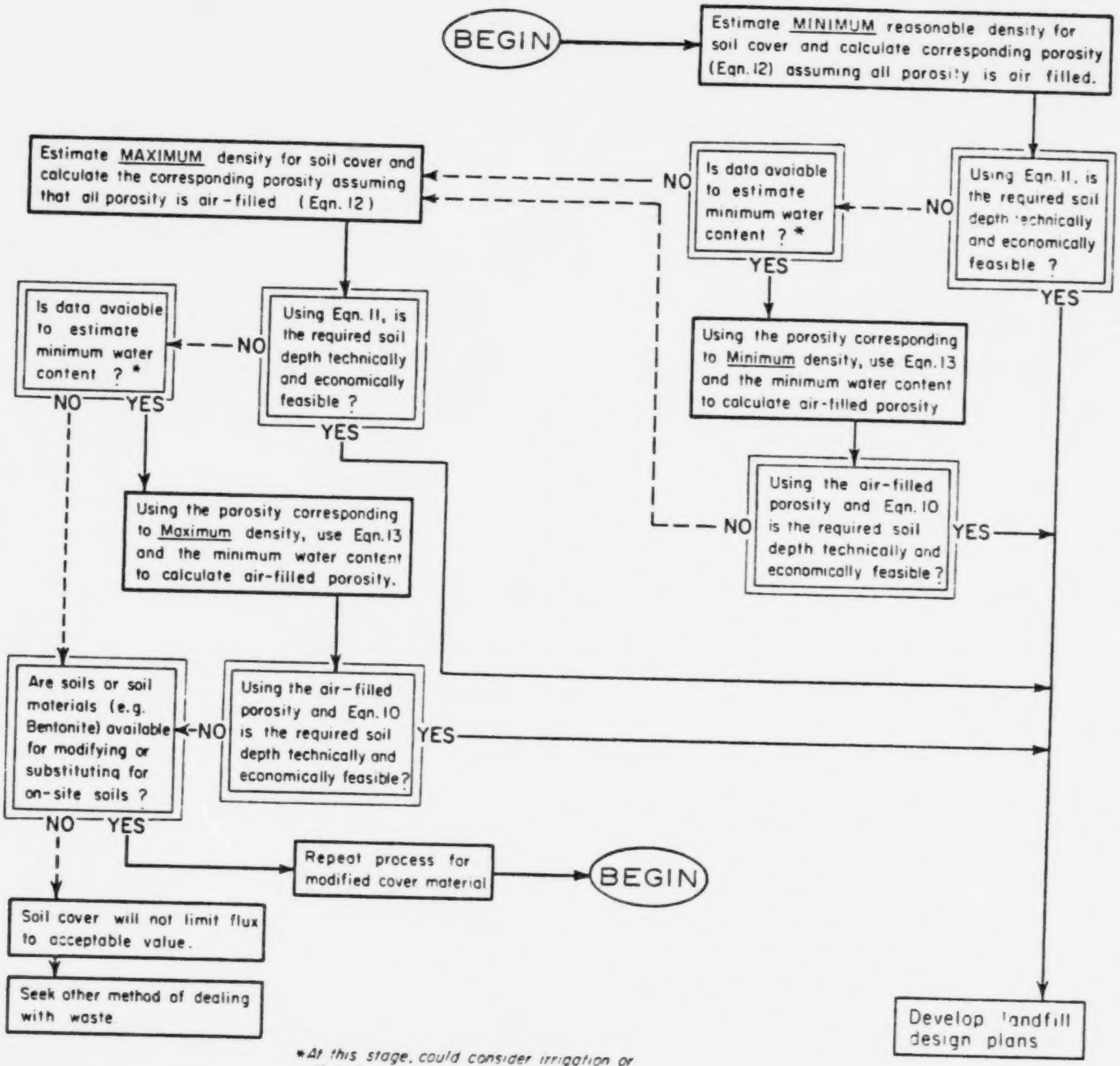
Some adaptation of the predictive techniques may be necessary to accommodate specific hazardous wastes and compounds of special interest. The principal gas modeled has been methane, a relatively small molecule, insoluble in water and a gas quite common in organic waste decomposition. While most of the predictive techniques just described were developed for gases originating within the land disposal facility, the same techniques can be used to describe gaseous releases from leachate or waste contaminated soils. Some adjustment of boundary conditions may be necessary, but the principles of flow and mass conservation are identical.

Emission of gases through the cover soils or directly to the atmosphere in the special cases previously described, is subject to the same driving forces discussed for flow through porous media. Diffusion and convection are both prevalent in gaseous releases through the cover system. The mass rate of release of gases in these situations are analyzed with respect to rate limiting functions such as film transfer for release from a free liquid, partial pressure gradients, and surface flushing or sweeping conditions which influence partial pressure gradients.

Farmer et al. (11) found the soil density, thickness, and moisture content to be the significant management variables which control gas release from soil covered land disposal facilities. Density and moisture content were important as they influenced the available pore volume through which mass transfer could occur, either by diffusion or convection. Farmer's work was performed specifically on HCB-containing wastes disposed at landfills. A flow diagram, Figure 3, was prepared to predict the depth of soil cover required to limit vapor flux. The study concluded placement of a cover system that minimizes air-filled porosity is important; disturbance of that cover system through cracking or small openings mitigates the control. Particular attention and long-term arrangements for maintenance of the cover system would be required in most cases. The duration and the requirements for satisfactory performance of the cover system can both be estimated using this technique.

Direct application of mass flux calculations for pure systems can be very misleading. Field conditions present many moderating or dampening situations. Even in the case of the surface impoundment, the liquid air interface will likely not permit the maximum flux due to impurities and non-ideal conditions. Use of cover systems such as soils, introduce another dampening factor, an impedance to the gas flow and consequently a reduction in the partial pressure gradient and thence a reduction of the rate of volatilization. Estimates of the magnitude of this dampening effect can be made for any volatile chemical in accordance with Farmer's recommendations or modifications such as proposed by Shen (30) or Thibodeaux (36).

Estimates of gas flow through cover systems can also be made using many of the prediction techniques proposed for estimating the extent of gas movement through soils surrounding the landfill facility. Some of the techniques could accommodate simultaneous predictions.


BEGIN
Estimate MINIMUM reasonable density for soil cover and calculate corresponding porosity (Eqn. 12) assuming all porosity is air filled.
Using Eqn. 11, is the required soil depth technically and economically feasible ?
NO
YES
Is data available to estimate minimum water content ? *
NO
YES
Using the porosity corresponding to Minimum density, use Eqn. 13 and the minimum water content to calculate air-filled porosity
Using the air-filled porosity and Eqn. 10 is the required soil depth technically and economically feasible ?
NO
YES
Estimate MAXIMUM density for soil cover and calculate the corresponding porosity assuming that all porosity is air-filled (Eqn. 12)
Using Eqn. 11, is the required soil depth technically and economically feasible ?
NO
YES
Is data available to estimate minimum water content ? *
NO
YES
Using the porosity corresponding to Maximum density, use Eqn. 13 and the minimum water content to calculate air-filled porosity.
Using the air-filled porosity and Eqn. 10 is the required soil depth technically and economically feasible ?
NO
YES
Are soils or soil materials (e.g. Bentonite) available for modifying or substituting for on-site soils ?
NO
YES
Repeat process for modified cover material
BEGIN
Soil cover will not limit flux to acceptable value.
Seek other method of dealing with waste
Develop landfill design plans

**At this stage, could consider irrigation or other treatment to maintain higher water content (if allowed by regulatory agency)*

Figure 3. Flow diagram for predicting depth of soil cover required to limit vapor flux through soil cover to an acceptable value.

(c) Summary

There are several techniques for predicting gas movement through porous media which have been specifically developed for land disposal situations. Similarly, the flux of gases through soil cover systems has been described by several investigators. While some of the techniques have been developed for specific compounds, most of the techniques are readily adaptable for any specific compound and will yield estimates specific for that compound. Although there is limited field verification of the techniques, all techniques indicate good success when predictions are compared to field observations. With more intensive monitoring at hazardous waste land disposal facilities, field data will be more readily available for more extensive verification of the prediction techniques.

(5) Leachate Migration in the Unsaturated Zone

(a) Background

The proposed regulation assumes that all disposal facilities will release some amount of leachate and therefore requires applicants to predict the rate of release and the extent to which leachate will move in soil liners and native soils during operation, closure, and post-closure. The regulation is silent about what assumptions are to be used in making these predictions or about which techniques are to be used. The applicant can assume that contaminants in the leachate will not be attenuated by interaction with the soils. In this case mixing with water in the unsaturated and saturated zones would be the only process limiting the spread of leachate and the leachate contaminants would be assumed to move at the same rate as the wetting front moving from the facility. The applicant also free to base the predictions on some degree of leachate-soil intraction (attenuation). A prediction on this basis would show that contaminants are retarded and do not move as quickly as the liquid front from the landfill. The state of the art for making leachate migration predictions based on no attenuation (contaminant-soil interaction) is supported by background information; while prediction methods that include the effect of attenuation is limited, but progressing rapidly. Consequently there is likely to be much more controversy surrounding permit applications where the applicant has chosen the latter prediction methods. This basis for allowing consideration of attenuation becomes a crucial issue for the proposed regulation.

(b) Discussion

When predictions on leachate movement exclude contaminant-soil interactions (e.g., adsorption, precipitation, ion exchange, etc.) problems are reduced to one of predicting mixing (e.g., diffusion, dispersion) of leachate with water present in the soil or aquifer before the disposal facility was operational. Examples of the many techniques for predicting mixing (2, 6, 13, 49, 51, 53, 54, 70, 76) are available. Because these mixing processes are most prominent in the saturated zone there is little discussion of them here. Refer to Section 6 of the background document on prediction of leachate movement in the saturated zone. There will be some mixing of leachate in the unsaturated zone but its effect on leachate composition and concentration will be slight when compared to the effect of attenuation. Procedures for assessing mixing in the unsaturated zone have been documented (1, 35, 64, 71, 75). Attenuation by contaminant-soil interactions such as adsorpton and ion exchange takes place in the saturated zone as well as in the unsaturated zone. The discussion below on techniques, problems, etc. applies to both zones.

It is recognized that biological and chemical degradation of organic materials occurs in soils (9, 15, 16, 62, 78). Experience with procedures for predicting how much such degradation will affect the concentration and composition of leachates from hazardous wastes is limited. Most degradation data are from surface soils where conditions are different than those expected below disposal facilities. There is data available on migration and degradation that will be useful (5, 13, 40, 41, 42, 45) to the permit applicant. It may be difficult to include degradation factors in any prediction of leachate migration without the support of field data on the movement of leachate from a very similar waste disposed of under similar conditions. Laboratory studies of degradation may aid in migration predictions.

After mixing and biological degradation have been removed from consideration there remain a number of processes (grouped under the term attenuation) that may change the concentration and composition of leachate as it passes through soil. Attenuation of waste leachates, pesticides, and other materials have been studied by a number of groups and the studies have developed techniques that can be applied to the design of disposal facilities. Because the techniques for predicting attenuation have had limited field testing (compared with techniques for predicting mixing) there is likely to be controversy if attenuation predictions are permitted to be included as part of facility design; nevertheless, this is no reason to exclude such predictions. The following discussions address a number of factors that are involved in the decision on whether or not to include attenuation predictions in predictions of leachate migration.

(i) Attenuation Occurs

Interactions between dissolved minerals and soils have been studied in the context of plant growth, renovation of sewage effluent, disposal of sewage sludge, radioactive waste, municipal waste, and industrial waste. Laboratory studies have documented the attentuation of metals and inorganic materials (1, 18, 20, 22, 23, 29, 33, 52, 61), pesticides, (8, 17, 27, 30, 42), and industrial and other organic chemicals (5, 25, 26, 28, 38, 40, 44, 61) in soils. These studies have identified differences in attenuation due to the nature of the contaminant (9, 11, 12, 15, 17, 18, 20, 22, 25, 26, 27, 28, 40, 52, 61, 62) the soil properties (4, 5, 9, 17, 19, 22, 25, 27, 28, 29, 34, 40, 45, 52, 61, 62) and the properties of the leachate in which the contaminant is carried (5, 19, 21, 23, 25, 28). The effects of contaminant type, soil properties, and leachate composition on attenuation under field conditions have been documented (1, 24, 29, 37, 52, 62). There is no doubt that the dissolved contaminants interact with soils and that these interactions affect the rate and total amount of leachate contaminants that will move through the soil.

(ii) Predictive Techniques are Available

As a result of the work listed above, a number of techniques have been developed for predicting the movement of attenuated contaminants through the soil. For contaminants that are not attenuated refer to the earlier, brief discussion of the mixing of leachate in the unsaturated and saturated zones. The predictive techniques for attenuated contaminants have, for the most part, been developed in studies of materials other than hazardous waste. The predictive techniques can be applied to hazardous waste because the contaminant-soil interactions are a function of properties of the materials involved (soils, contaminants, etc.) rather than the type of waste. At present, no single technique is clearly superior to another and few have received sufficient field testing, to establish a high level of confidence for their predictions. The lack of field testing on hazardous wastes, however, is not a bar to the use of the techniques. The proposed regulation recognizes that predictions are likely to be a range of values and provides for tri-annual refinement of the prediction using monitoring data from the facility. Technical difficulties that must be overcome in making this application are discussed later. The techniques available vary in the amount of information required, the cost and technical difficult, their applicability to complex geohydrologic settings, applicability to different waste types, and the precision and accuracy of the results. Some examples of the different techniques are listed below.

Screening procedures (16, 27, 68) use limited data and simplifying assumptions to predict most likely routes of transport (air, water, food chain, etc.), the relative amounts of the materials transported, and the potential contamination to a given site. These procedures are more useful for identifying extreme problems and sorting site-waste combinations into broad classification than in making precise predictions of contaminant movement which can be verified with monitoring data.

Mixed batch techniques (18, 26, 33, 34, 62) use open or closed vessels to contact the waste or leachate with soil and subsequently determine the retention or release of contaminants of interest. A sequence of batch tests where the liquid is separated from the soil and then added to the next batch can be used to simulate passage of leachate through a soil profile. Batch techniques are less costly and time consuming than soil column techniques and have given reasonably good estimates of removals observed in column studies with disturbed soils. Batch techniques predict greater attenuation and dilution than is observed in column studies with undisturbed soils.

Soil thin layer chromatography (5, 17, 25, 28, 31, 32) is a screening tool for obtaining an estimate of a contaminant's leaching potential. It is similar to conventional thin layer chromatography except that the soil is substituted for the usual adsorbent phases (silica gels, oxides, etc.). This technique would be most useful for determining the rate of movement of a contaminant relative to the rate of movement of a material whose mobility under field conditions is already known.

Soil columns (9, 18, 19, 23, 29, 31) are containers filled with either disturbed or undisturbed soils. Materials are placed on top of the column and liquids added to leach substances downward through the soil. In addition, leachates generated elsewhere can also be added directly to the column. Columns may be operated saturated, partially saturated, or unsaturated. Although they are difficult to replicate and time consuming to operate, soil columns have the advantage over other laboratory leaching procedures because they include the effects of both mixing and attenuation, particularly when undisturbed soils are used.

Simulation models (2, 6, 7, 8, 13, 14, 49, 53, 54, 55, 56, 59, 63, 64) are descriptions of how the soil-solute systems behave in response to changes in conditions. The input information may consist of fundamental physical and chemical properties of parts of the system or it can consist of empirical data gathered from other procedures, such as batch or soil column studies. Categories of available models and a discussion of their relative merits have been published (2, 7, 70, 72). Some models which were developed to predict the behavior of water at the soil surface (agricultural runoff, small watershed hydrology) include submodels for predicting movement of water or solutes downward and laterally through soil (10, 36, 43). This is not a complete listing of the work that is being done on predicting movement of substances through soil. Even if the choice were to be limited to the work cited here, nevertheless, there are available a variety of techniques that can be applied to the problem. These techniques vary in technical difficulty, cost, and the precision, accuracy and complexity of their results. Though there is clearly a data base from which techniques can be drawn, application of these techniques may, in some cases, require ingenuity on the part of the applicant if such predictive techiques are utilized.

Common to all techniques will be the need to conduct studies with the waste and the soil from the proposed facility. Although it may be possible to estimate soil and waste properties to screen several sites, available information is not likely to be sufficient to make meaningful predictions about a specific site.

(iii) Technical Difficulties

Because predictive techniques were orignially developed for conditions other than those that will be encountered in hazardous waste disposal, some technical difficulties will be encountered. These must be taken into consideration by applicants attempting predictions and by those reviewing applications.

Flow system

The path and rate of movement of liquids must be defined in order to predict the movement of leachate contaminants. For sites in homogeneous materials this may be much easier than predicting attenuation; in more complex settings defining the flow properties such as permeability or hydraulic conductivity, there exists not only the problem of taking measurements in fine textured soils (clays) using techniques developed for coarser textured soils (e.g., sands) but also the problem of variability of soil properties even in soils that seem quite uniform (4, 48).

Availability of leachate

Unless another facility accepting the same type of waste is available as a source of leachate, the applicant will need to either generate leachate in the laboratory from a sample of waste in order to measure contaminant properties or use empirical predictive procedures. Assuring that laboratory generated leachate is similar to leachate from the waste under field conditions will require careful thought and attention to detail. Procedures for doing this are limited but, recently, work has been done in cnnection with the development of Extraction Procedure for RCRA Section 3001 and with attempts to develop related procedures for wastes that are not disposed of with municipal solid waste. It should be emphasized that the leachate used in predictive procedures should be similar to field leachate to enhance accuracy. Refer back to Section 3 on leachate composition for further discussion.

It will be much more difficult to generate a laboratory leachate for facilities that accept more than one type of waste. Not only would several wastes have to be used, but the relative proportions would have to be similar to the field situation and the sequence of leaching would also have to be considered unless the wastes are to be thoroughly mixed in the field. These sort of leachate problems will make it extremely difficult to predict leachate attenuation for facilities that will be placing a number of wastes in contact with each other.

Analytical problems

The separation, cleanup, and chemical analyses of leachate constituents from a hazardous waste is a substantial problem. Many analytical methods have been developed to detect substances in fairly clean matrices. Methods for analysis in sewage and industrial wastes (25, 26, 28, 33) may require modification before being applied to waste leachates. Once an applicant has generated a leachate for use in a predictive method it may be necessary to adapt existing techniques to make them applicable to leachate analysis.

Similarly, the methods for determining properties of contaminants and soils have not been used extensively in the presence of waste leachate and therefore may need modification. Methods for determining many of the contaminant properties have been documented for substances in single solutions (3, 26, 28, 29, 32, 38, 39, 41, 45, 57, 58, 60, 69). This can serve as a base for similar work when multiple solutions of contaminants are analysed.

The contaminant-soil interaction behavior of the hydrophobic non-ionic organic compounds has been studied with more success than other organics. A number of studies (5, 14, 25, 26, 27, 28, 30, 40, 41) have demonstrated how to greatly reduce the number of factors which need to be considered in accounting for attenuation by referencing to a few properties such as soil organic content or surface area. Several other approaches have been explored (3, 12, 47) to estimating contaminant-soil interaction properties; their applicability is dependent on the variety of materials that have been used in their development.

Finally, it should be noted that most research work has been done during adsorption of contaminants onto soil; the degree of reversibility of this process needs further attention.

Testing predictions

Because of the uncertainties in the prediction procedures and in the processes of gathering input data, there will be uncertainity in the final prediction. The proposed regulation recognizes this and provides for a tri-annual up-dating of predictions using monitoring data from the facility. Monitoring will be conducted via wells that draw water from the saturated zone of soils below and around the facility. Monitoring in the unsaturated zone has not been provided for (except for land treatment facilities) because of reliability problems with the devices and the added difficulty of maintenance. Where there is a thick unsaturated zone below a facility it could be quite a long time before any contaminants reached the monitoring points in the saturated zone and it could also be difficult to make any check on predictions of leachate movement within a reasonable time. Where a thick unsaturated zone exists and the degree of uncertainty in the leachate movement prediction is great, the applicant may consider installing unsaturated zone monitoring (37, 46, 74) close to the bottom of the facility which would enable him to make a predictive test before a long time has elapsed. In such a case, the unsaturated zone monitoring equipment would be a temporary or expendable part of a total monitoring program.

(iv) Precedents

Prior discussion on the attenuation of leachate contaminants by soils have raised questions about the appropriateness of allowing the inclusion of attenuation in the prediction of leachate movement. Non-technical considerations for including leachate attenuation are mentioned as background for the proposed regulation.

An Office of Solid Waste study (72) completed in 1978 examined approaches to pollution prediction for waste disposal siting and concluded that the simulation model approach (which includes consideration of attenuation) would only be a suitable tool in the long-term, after considerable development and standarization. The regulatory approach envisioned at that time relied on standard procedures (such as Section 3001 Extraction Procedure) that would be specified for use in all cases. Since that time, the state of the art in prediction procedures has become better understood and, thus, a more flexible regulatory approach has been adopted. As a result, through knowledge gained on predictive procedures, the proposed regulations allow for the use of simulation models or other predictive techniques for assessing the effect of attenuation on leachate movement. The regulations recognize that there may be combinations of waste types, hydrologic settings, and technical abilities of an applicant who can make predictions of attenuation appropriate for that case.

Several states are cited in the Office of Solid Waste study (72) as presently requesting information from permit applicants regarding the attenuation capacity or activity of soils and earth materials at proposed disposal facilities. If attenuation were excluded from consideration in the proposed regulation it would be reasonable to question why the Agency would not recognize and allow consideration of an effect which could increase the acceptability and potentially reduce the cost of land disposal facilities.

A simplified vertical-horizontal routing model (13) was developed for the Oregon Department of Environmental Quality. This model includes provisions for contaminant attenuation by soil. Although the model has not yet been extensively verified against field data, it has been used in evaluating the impact of various organic chemicals on ground water conditions. The Office of Solid Waste Report (72) notes that the results of these evaluations were not incorporated in landfill design requirements. However, the existence of the model and its limited use by a state agency are a part of the background for the concepts in the proposed regulation.

The Toxic Substances Premarket Testing Program (68) includes some detailed consideration of the attenuation and mobility of chemicals in soils and requires submission of that information. A background document has been issued (69) describing methods for collecting this information.

While none of the examples discussed above constitute a compelling basis for including consideration of attenuation in the proposed regulation, they do indicate that the proposed regulation is by no means the first instance of such an inclusion and suggest that there is a basis for doing so.

(v) Consequences of not considering attenuation

If the proposed regulation had excluded attenuation as an allowable consideration in predicting the mass rate of leachate migration, the Agency could expect to be critized for ignoring the existence of a phenomenon that is generally acknowledged to take place. Moreover, the Agency would be guilty of failing to make use of available, though rudimentary, technology, and also of limiting the creativity of applicants in devising solutions to disposal problems.

If attenuation could not be considered in predicting leachate movement the major remaining mechanism would be limited to dilution and dispersion. Using only these two mechanisms would yield predictions of much greater travel distance than if attenuation were included and would also lead to the need for much greater buffer zones resulting in less economically viable facilities at a time when disposal capacity is expected to be limited.

Finally, to exclude the use of attenuation in leachate movement predictions would severely inhibit development of the ability to make such predictions and thereby arrive at a realistic compromise between cost and protection. Improvement in the ability to incorporate attenuation in the prediction of leachate movement will be costly; however a likely impetus to such a improvement would be the need for the techniques in situations such as disposal management where the costs (and potential savings) are great.

(c) Summary

The proposed regulation allows consideration of attenuation (contaminant-soil interactions) in making predictions of leachate movement in soil. It is acknowledged that attenuation takes place in soils and that it acts to limit the amounts and rates of movement of pollutants. Techniques are available for predicting attenuation and the state of the art is advancing. The proposed regulation recognizes existing limit to the state of the art and includes provisions to compensate for these limits.

Finally, exclusion from consideration of attenuation could cause several adverse effects.

(6) Leachate Migration in the Saturated Zone

(a) Background

Once a substance released from a discharging facility actually enters the saturated zone, the predictive techniques for migration and environmental fate become much more reliable (7,19,31). The major weakness in the development to date of contaminant transport models in the saturated zone is due to difficulty in determining a field coefficient of dispersion, and in quantifying chemical reaction terms (1). As mentioned in Section 5 concerning the unsaturated zone, mixing processes are more prominent in the saturated zone. Contaminant-soil interactions are relatively less significant in saturated zones; their discussion centers in Section 5.

The proposed provisions of Part 122 include a requirement that the owner or operator must predict the migration of contaminants from the facility in the ground water. Mathematical simulations are one method by which these predictions could be made. Additionally, the owner or operator is required to implement a ground water monitoring program capable of determining permit compliance. Again, mathematical simulations can be utilized to demonstrate this capability.

Mathematical simulations submitted to the Agency to demonstrate the adequacy of the system or performance of the facility must be documented and calibrated. Agency guidance will establish the limits of verification and validation. Also, model capabilities may be demonstrated using standard test cases established in Agency guidance manuals. This background document expresses the Agency's intent regarding the limits, utility, and procedural constraints of mathematical simulations of the migration of contaminants which have entered the ground water from hazardous waste management facilities. Several dozen mathematical simulations of ground water contamination processes useful for environmental prediction and analysis have been cataloged by the Holcome Institute for the EPA (4). Saturated water models comprise the greatest and most sophisticated portion of these, but ground water modeling is in an early stage of development, and, as in the state of the art of most developing disciplines, the beginning is broader than deep. Many of the differences between competing ground water models are less significant than the variations within each. Many which have been designed for one application are being modified for improved performance in another.

Anticipating the possibility that model selection, a critical juncture in performing the required predictions, will require review, the Agency intends to develop a review protocol. The objectives and procedures are addressed in this background document after a discussion of the acceptable applications, the limitations for regulatory purposes, and a few exemplary cases.

(b) Trust and Skepticism

The Agency's position at the time of proposal of these regulations is to encourage skeptical, limited use of mathematical models as a basis for predicting the fate of contaminants and for demonstrating monitoring competence in fulfillment of the permit application requirements. Limits of encouragement exclude very simple hydrogeologic settings, for example, in which the rigor of modeling is just not warranted, as well as very complex settings in which intricate fracturing and layering elude quantification. Skepticism is particularly encouraged with regard to selection of the source term, the diffusion coefficients and the expressions of soil-leachate interactions. For the vast majority of approvable facilities, however, mathematical simulation provides an effective method of developing and expressing the most probable direction and rate of migration of substances which could be released by a proposed facility.

(c) Acceptable Levels of Confidence

Model confidence factors will be developed in guidance manuals. They will vary as dependents of data quality as determined by the number of samples, homogenicity of site characteristics, complexity of hydrogeologic settings, etc. Where subjective judgments are required, the manuals will provide procedures to standardize the values as much as possible.

Confidence ratings will be developed by the applicant. The level of confidence achieved will be evaluated by the permit issuing authority in keeping with the perceived environmental and health danger at each proposed facility.

(d) Discussion

Once leachate enters the ground water, the major determinant of the rate and direction of movement is of course the movement of the ground water itself (2). The problem in predicting the movement is then a combination of ground water flow prediction with prediction of leachate dispersion, adsorption, convection, diffusion and other factors which may tend to differentially act on the leachate (3, 5, 11, 13, 16, 17, 18, 30). In free flowing aquifers, the movement due to hydraulic head differential, called advection, is the dominant means of saturated zone contaminant flow and models which only consider advection may be appropriate. Other models jointly considering dispersion and advection may be more useful in slower moving aquifers (1, 27). Complexities in the site hydrogeology heighten the value of joint models because dispersion is enhanced as contaminants migrate selectively around less permeable strata. However, the difficulty of neasuring dispersivity and the numerical difficulties in solving the great complexity of equations tend to detract from their value (1).

Chemical interactions may be incorporated in either advection only or advection-dispersion models. These interactions are difficult to separately measure or estimate; moreover, the added complexity can be crippling to models of non-homogenous settings.

Advection models are useful in estimating minimum time for arrival and probable pathways. For many applicants, these two determinations will be sufficient, as the cost and uncertainty of modeling to determine the probable arrival of concentrations at a point may be stifling.

(i) Diffusion, Dispersion

Dispersivity is described as a convenient mathematical quantity with obscure physical significance (1, 6, 48). It is not a directly measurable field condition, but rather, it can be calculated, differently at different scales, from several measurable values. It is sometimes disparagingly referred to as a "fudge factor" fitted to the model and site at the scale considered. Dispersivity is also expressed as a characteristic mixing length of a soil or strata; it is related to the homogeneity of the geology, which of course varies as the modeled scale progresses from micro to macro (29).

This indirect or fitted nature of dispersivity is problematic for its use in permit applications. Ideally, a reviewer would prefer a simple, precise measure which is easy to verify. Tracers provide the only direct pre-construction, field determination of dispersivity. Problems incumbent with ground water tracer studies, however, severely restrict their value for most permit application cases. The tracer test for dispersivity involves monitoring the rate change of the concentration of injected tracers across the pathways from the proposed site. In order to encounter the modeled geologic idiosyncracies at a useful scale, the minimal tracer test will require many months to complete. Extreme care must be observed in selecting the length of screen for tracer sampling wells for instance; too large a sample zone will provide a falsely mixed sample, indicating more than actual attenuation or dispersivity. Slug injections of tracers render vastly different results than steady-state injections, yet the modeled facility may actually emit a combination of steady-state and slug injections, leaving the modeler yet another unknown. Sorting the effects of dispersion from other tracer decay mechanisms such as adsorption, decomposition, soil interaction, etc., as well as behavioral differences caused by the future leachate's differing temperature or viscosity, for instance, can be difficult, also. Local histories of similar facilities may prove to be a more reliable predictor. "Environmental" measurement of dispersivity using substances present in the aquifer prior to testing, such as intruded sea water or tritium introduced after atom bomb "fall out," are not generally applicable to the scale significant for facility permit applications. Complex site geology may suggest not only avoiding regional-scale dispersivity, but even calculating several discrete values within the pathway of concern, with spatial distribution segmented and longitudinal and transverse dispersivity varying across very small increments (8, 12, 14, 16).

(ii) Techniques

There are a wide variety of modeling techniques applicable for various phases of prediction and or monitoring system design (10, 25). Each technique has strengths and weaknesses, none are universally suitable.

The use of models in ground-water studies has three main phases; system conceptualization, history matching or model calibration, and prediction. Most applications involve each of the three phases; however, the relative effort devoted to each phase is application dependent.

System conceptualization involves organizing available information on the ground-water system in an internally consistant framework; the information is posed in terms of a qualitative model. The qualitative model is translated into mathamatical terms such as boundary conditions, initial conditions, and hydrologic parameters. An appropiate ground-water model, which is quantitative, can then be applied to improve the model. The use of the model involves checking various observations and determining the sensitivity of the system responses to hydrologic parameters and assumptions. The results of the system conceptualization provide a basis for designing data collection efforts. Use of models at this stage not only forces the hydrologist within a tested framework, but also gives guidance in terms of data requirements (20).

History matching or model calibration will refine the estimates of hydrologic parameters and boundary conditions by comparing model results with observed data (28). In the early part of a study, observed data will consist of aquifer tests. Estimates of parameters are changed to improve the comparison. The history matching procedure can be done by an automatic regression approach, followed by sensitivity analysis and continuing data collection activities.

The final phase is the prediction of future system behavior, normally the shortest part of the study. Predictions are based on model results using the best estimate of system parameters obtained by history matching. Assessing the uncetainty in the predicted results should be accomplished by reiterating the sensitivity analysis.

(e) Test Case Comparisons

The Agency intends to develop an evaluation protocol to be used by owners or operators in demonstrating the capabilities and sensitivity of any mathematical model submitted in support of monitoring systems or of predictions of migration in the saturated zone. The protocol will consist of a set of standard test cases representing a spectrum of facility and site characteristics and a set of required outputs from each model for the test case. Model performance may then be judged, at least in a comparative way, as to relative sensitivity to certain parameters. While the Agency does not expect this evaluation protocol to influence the confidence ratings in paragraph c, above, it does appear to offer some measure of assistance to the permit review process.

Model testing involves the following two determinations:

° Does the model accurately simulate the phenomon for which it has been designed?

° Do the numerical approximations accurately solve the mathematical equations that constitute the model?

Methodologies that test models include comparisons with analytical solutions, comparisons with empirical data, and checking that conservation properties (mass balance) hold.

Testing a numerical model consists of different levels of error elimination; the numerical solution will be compared with known analytical solutions to remove logic errors in solving the equations. Numerical solutions are compared with laboratory and field observations to remove logic errors in equations describing the physics. Therefore, data required for the test cases may include analytical solutions, laboratory results, field applications, hypothetical problems, and/or physical analogues. There are several analyical solutions available for subsurface flow. Classical solutions for radial flow include those by Theis and Hantush. Avodonin (3) presents an example analytical solution for heat and fluid flow, whereas Ogata and Banks (22) give an example analytical solution for solute and fluid flow (6, 9, 14, 15, 21, 23, 24, 26).

To test the represented physics and chemistry, the results may be validated against known laboratory or field results. A feasible approach would be to use a tracer test senario, since the geological and hydraulic conditions might be expected to be comparitively well defined in such a case. Laboratory studies have been performed for many related problems. Models involving solute transport could be compared with results from column studies such as those obtained by Griffen and Shimp.

Another level of testing is the comparison of one code against another. Such comparisons may be used to demonstrate the influence of different physico-chemical parameters on the results of the simulation of a hypothetical site. The properties of the hypothetical site selected for the simulation should be close to those deemed realistic for a candidate site. At this level of comparison, the correct answers to the calculation are not known. Considering that some of the models include effects that have a very strong influence on the output, the results might be expected to be scattered over a wide range.

(f) Summary

Modeling and models are the subject of much controversy in their regulatory application. They are seldom presented with an air of certainty. However, it should be remembered that many situations will occur which are well within the capabilities of mathematical modeling. Where a prediction of plus or minus 50 percent may represent the outer limits of confidence, however, it is still possible that the regulatory task to be assigned to model is simply to predict the future presence or absence and not the concentration.

The Agency intends to recognize the value of mathematical models, to permit and encourage their limited use in demonstating the fate of discharges to groundwater and the adequacy of monitoring schemes for instance, and to remind users and reviewers of models of the associated shortcomings and uncertainties (28).

(7) Leachate discharge from the saturated zone

(a) Background

One of the major uses of models intended by the Agency is as a mechanism to test predictions of effects on flowing surface waters and withdrawals of ground water through wells or collection devices. Withdrawals or discharges from a migrating plume, if they exist, represent conditions, often as boundry conditions, which must be taken into account in the development of saturated zone models. Therefore, the mechanics of analysis of discharges and withdrawals from the saturated zone is an integral part of the analysis of migration within the saturated zone. Analysis of discharges and withdrawals is usually the objective of saturated zone modeling.

(b) Discussion

Since the objective of the analysis of the migration of ground water affected by discharges from hazardous waste land disposal facilities is to predict effects on flowing surface waters and ground water withdrawn through wells or collection devices, it is with respect to this need that the quality of the necessary models may be judged. In most cases, it is expected that the analysis will be concentrated primarily on the migratory pathway of a leachate plume in ground water as it seeks a normal discharge to the surface environment. This is the situation which will prevail for an owner or operator who can show that his facility will comply with the ground-water protection standard in §264.2.

As noted in the summary to the previous section, the regulatory task in this case will be simply to predict the future presence or absence and not the concentration. The precision of the necessary modeling effort will be quite variable depending on the real risk of exposure through ground water withdrawl. If it is known, or it can be established, that no ground water withdrawal for use exists, or will be initiated in the future, within or proximate to the migratory pathway of the leachate plume; simple forms of modeling will suffice. Where the pathway to natural discharge outlets is relatively short, limited field data will be required; and the model may be a simple hydrologic calculation which can be accomplished by hand. The task will be even simpler for existing facilities since the migratory pathway may be measured, and prediction will not be required to represent it accurately. However, it will still be necessary to make quantitative predictions of the mass rate of waste constituents and byproducts which will reach surface waters, but often the margin for acceptable error in such predictions is large and maximum potential effects can be demonstrated on the basis of the mass rate of deposition in a facility or a determinate mass rate of discharge from the facility controlled to a desirable low rate by the facility design. The necessary precision of such quantitative predictions of potential effects on surface waters will of course vary with the amount of flowing water in the surface water body. Therefore, the necessary precision will be greater for facilities located so that the ultimate discharge of affected ground water will be to a small stream than it would be for facilities located so that the ultimate discharge would be to a large river or the ocean.

The greatest precision in predicting (or modeling) the effects of plume migration will exist when a variance from the ground water protection standard is required. In such cases, the affected ground water is being or may in the future be withdrawn or collected for use. The objective of the Agency is to avoid such situations to the extent that it is possible without arbitrarily denying a permit applicant the opportunity to show that no adverse effect would result. When active or potential use of affected ground water is a factor that must be considered, there is no substitute for maximum possible (i.e., state of the art) precision in predicting potential adverse effects on the users of the ground water. It is in this circumstance that qualitative and quantitative modeling will be a practical requirement for a sucessful showing in the permit issuance process, and it is quite likely that sophisticated computer modeling based on extensive field data will be needed.

(c) Summary

The goal associated with the use of any particular predictive tools such as ground-water modeling in the permit issuance process is to satisy the permit applicant, the permit issuing authority, and the public that a permit may be issued. It should be obvious that when the potential for interference with use is real, the data and analysis requirements needed to assure an understanding of the systems grow. The public whose use may be adversely affected will demand such assurance to protect their interests, and it if is not provided in the permit issuance process, will pursue other means to avoid exposure to risks they fear. Adequate information, as a basis for decision, is the only viable means of overcoming that fear.

As noted, it is expected that the information required will most often be used to show that there is no substantial or unique risk of exposure because ground water use will not be at issue. When ground water use is at issue, it is quite likely that permit applicants will choose other means to meet their disposal objectives which will avoid the need to deal with the complexity of adequate information to show acceptable risk.

For existing facilities which do affect ground waters which are being used, the understanding of that fact, which the informational requirements will force, may result in the elimination of the risk through the discontinuance of use by means independent of the permit issuance process. If the ground waters are not presently used, the understanding may serve as an incentive to preclude future use and interference by restricting use. Although these examples of potential restriction of use are not, at first glance, protective (or an agency objective), they may be both practical and cost effective for the regulated community. This is especially true since recovery of adversely affected ground water is often not possible in a practical sense. Continued use of ground water which is already adversely affected could potentially furthur environmental goals by not inducing pressure to allow unaffected ground water to be placed at risk by facility construction. In any case, both the restriction and the discontinuance of use of affected ground water would result in compliance with the ground-water protection standard of §264.2 and would be means available to an owner or operator seeking a permit under §3004 of the RCRA.

D. Regulatory Language

(d) Informational requirements for permitting discharges from land disposal facilities. Except as provided in paragraph (e) of this section, each owner or operator applying for a permit to dispose of hazardous waste into or on the land shall file the following information as part of his application:

(1) A definition of the specific hazardous wastes to be disposed of in each disposal facility operational unit, including;

(i) the specific wastes by hazardous waste number when applicable.

(ii) the expected rate of deposition of each specific waste including both wastes defined as hazardous wastes in accordance with §261.3 and any other waste to be disposed of in conjunction with such hazardous wastes.

(iii) the maximum rate of deposition of each specific waste described in accordance with §122.25(d)(1)(ii) for which permit authorization is being requested.

(2) A definition of the rate of mass transport of leachate and gases from the land disposal facility, including;

(i) the mass rate of hazardous wastes, and the decomposition byproducts of hazardous wastes expected to leach or otherwise escape from the facility,

(ii) the mass rate of any other wastes and the decomposition byproducts of such other wastes expected to leach or otherwise escape from the facility,

(iii) the mass rate of infiltrating rainwater and other liquids disposed of or generated within the facility expected to leach or otherwise escape from the facility, and

(iv) the maximum mass rate of infiltrating rainwater, any other liquids to be disposed of or generated within the facility, hazardous wastes and any other wastes to be disposed of within the the facility, and the decomposition byproducts of such hazardous wastes or other wastes including gases expected to leach or otherwise escape from the facility.

(3) A definition of the earth materials above the zone of saturation which will be in contact with leachate discharging from the land disposal facility and gases released from the facility and the leachate, including;

(i) the lateral and vertical extent of the expected migration of leachate in any materials emplaced to control the rate of leachate migration.

(ii) the lateral and vertical extent of the expected migration of leachate in each natural earth material formation determined to exist during site investigation studies required in paragraph (g).

(iii) the lateral and vertical extent of the expected migration of gases through any materials or wastes emplaced within the facility.

(iv) the lateral and vertical extent of migration of gases in each natural formation determined to exist during the site investigation studies required in paragraph (g).

(v) the maximum lateral and vertical extent of earth materials above the zone of saturation and the area at the surface of the ground or the waste for which authorization to be in contact with leachate discharged from the facility or gases released from the facility and the leachate is being requested.

(4) A definition of the earth materials in the saturated zone which will be in contact with the leachate discharged from the land disposal facility and the extent and rate of leaching, including;

(i) the mass rate of transport of infiltrating rainwater, any other liquids to be disposed of or generated within the facility, hazardous wastes or any other wastes to be disposed of within the facility, and the decomposition byproducts of such hazardous wastes or other wastes; expected to leach from the facility to the ground water.

(ii) any alteration in the vertical elevation of the zone of saturation expected to occur due to the existence of the facility and/or the discharge from the facility to the saturated zone.

(iii) the transverse, lateral, and vertical extent of the expected migration of leachate within each natural earth material formation in the saturated zone determined to exist during site investigation studies required in paragraph (g).

(iv) the maximum transverse, lateral, and vertical extent of earth materials in the saturated zone for which authorization to be in contact with leachate discharged from the facility is being requested.

(v) the maximum mass rate of transport within the saturated zone of infiltrating rainwater, any other liquids to be disposed of or generated within the facility, hazardous wastes or any other wastes to be disposed of within the facility, and the decomposition byproducts of such hazardous wastes or other wastes for which permit authorization is being requested.

(5) A definition of the discharges and/or withdrawals of ground water mixed with leachate, including;

(i) the mass rate of discharge from the saturated zone of liquids to be disposed of within the facility, liquids other than water which will be generated within the facility, hazardous wastes or any other wastes to be disposed of within the facility, substances solubilized from earth materials by leachate, and the decomposition byproducts of such hazardous wastes, liquids, or other wastes or substances; into any flowing surface waters, any standing surface waters, or to the ground surface within the zone of containment.

(ii) the maximum mass rate of discharge from the saturated zone of liquids to be disposed of within the facility, liquids other than water which will be generated within the facility, hazardous wastes or any other wastes to be disposed of within the facility, substances solubilized from earth materials by leachate, and/or the decomposition byproducts of such hazardous wastes, liquids, or other wastes or substances; into any flowing surface waters, any standing surface waters, or to the ground surface within the zone of containment for which permit authorization is being requested.

(iii) the mass rate of withdrawal from the saturated zone of liquids to be disposed of within the facility, liquids other than water which will be generated within the facility, hazardous wastes or any other wastes to be disposed of within the facility, substances solubilized from earth materials by leachate, and the decomposition byproducts of such hazardous wastes, liquids, or other wastes or substances into any well or other ground water collection device, except monitoring wells or collection devices installed or to be installed to monitor or characterize the leachate and the ground water.

(iv) the maximum mass rate of withdrawal from the saturated zone of liquids to be disposed of within the facility, liquids other than water which will be generated within the facility, hazardous wastes or any other wastes to be disposed of within the facility, substances solubilized from earth materials by leachate, and the decomposition byproducts of such hazardous wastes, liquids, or other wastes or substances; into any well or any other ground water collection device, except monitoring wells or collection devices installed or to be installed to monitor or characterize the leachate and/or the ground water.

3. Variations in precision - §122.25(e)

A. Proposed Regulation and Rationale

This portion of the regulatory requirements for information was not addressed in the Agency's 8 October 1980 notice of its intended approach to permitting hazardous waste land disposal facilities.

B. Summary of Comments

Commenters on the 8 October 1980 notice did recognize and assert that the informational requirements discussed in the notice were not equally applicable to all situations and suggested that the requirements be triggered by demonstrated need.

C. Discussion

The Agency decision to include explicit statements in the regulations concerning variation in required precision is responsive to comment. The regulatory statements are keyed to specific paragraphs of §122.25(d). Issues related to needed precision are also covered in the discussion on that portion of the regulations.

(1) Waste loadings - §122.25(e)(1)

Section 122.25(d)(1) requires a definition of what wastes will be disposed of in a facility. This information is considered a minimum requirement for all facilities. No analysis is possible if one is not aware what waste is to be handled in a facility.

(2) Discharge and emission rates - §122.25(e)(2) & (3)

Section 122.25(d)(2) establishes the requirement to define the rate of releases (discharges and emissions) from a facility. Since no discharge to ground water is allowed from facilities (surface impoundments and waste piles) used solely for storage or storage and treatment, paragraph (i) establishes that no definition is required for such facilities. There is a caveat to the provision in that if an owner or operator chooses to provide a positive collection system in addition to a leachate detection system, information on the expected rate of discharge is required. Such information would be needed to evaluate the discharge and the need for treatment. Such a situation would exist in a storage and treatment surface impoundment when the treatment is an in place filtering system designed to provide solid/liquid phase separation prior to liquid withdrawal rather than a piped outlet within the impounded waste.

Paragraph (ii) allows analysis of facilies designed to introduce liquids into the land to be based on the liquid deposition rate. This provision is, of course, only applicable during the active use of a facility and in certain (areally large) seepage facilities, rainfall loadings may be significant.

Paragraph (iii) allows direct emissions from land disposal facilities to the atmosphere to be considered in conjunction with all facilitiy emissions. Direct emissions from land disposal operational units will commonly be a minor part of the total gaseous emissions from a major hazardous waste management facility which may include such operational units as tanks, basins, storage areas, handling and transfer areas, stills, evaporators, and incinerators.

Paragraph (iii) establishes the fact that the rates of discharge from a land disposal facility cannot often be determined exactly especially since discharge rates will often be influenced by the variances of weather. It is implicit in the requirements that discharge must usually be expressed by averages, ranges, and expected extremes. As noted in the language of the paragraph, the "best estimate" results will be subject to verification (with respect to extremes) and improved precision based on monitoring and modelling.

Section 122.25(e)(3) more explicitly describes the type of information expected to define the volume and character of leachate. The need for accurate volumetric information is considered to be of major importance since many of the important design features of land disposal facilities are intended to control the rate of liquid migration. The physical characteristics of the liquid (leachate) are also important to facility design. In most cases it will be sufficiently accurate to consider the leachate to be physically equivalent to water; however, it must be established that such an assumption is valid. Liquids that will not mix with water will usually behave differently than water, and substances which do mix or dissolve in water can change its physical character.

Important physical parameters of liquids and leachates that can be expected to discharge from a facility must be defined independently. The parameters which must be defined are viscosity, specific gravity, and surface tension as required by paragraph (i).

The viscosity of any liquid will vary with temperature, and the rate at which any liquid will flow through a porous media such as soil is inversely proportional to the kinematic viscosity. Examples of the variability of kinematic viscosity can be expressed with reference to familiar fluids; gasoline could have a kinematic viscosity half that of water, whereas engine lubricating oil could have a kinematic viscosity four hundred times that of water.

Liquids with specific gravities higher or lower than water will tend to sink or float respectively in a water system; and the surface tension of a liquid will influence the capillarity (based on the adhesion of the liquid to the soil and cohesion of the liquid itself) of the liquid in contact with the soil.

All of the above parameters are directly measurable by standard techniques in the laboratory.

Describing the chemical characteristics of a leachate is much more problematic. Paragraph (ii) describes the degree of characterization that is expected in terms of the expected or probable fate of contaminants. The "best estimates" of contaminants (constituents and decomposition byproducts of the waste) which will be present in a leachate must be based on an understanding of the probable bio-chemical reactions which the waste can be expected to undergo. The regulation allows such "best estimates" to be based on "reliable reference sources of data" or on "independent study".

The Agency has produced a report ("Water Related Environmental Fate of 129 Prioity Pollutants", EPA-440/4-79-029a, December 1979) which describes the probable fate and transport of a number of toxic chemicals in the environment with respect to a variety of chemical, physical, and biological processes such as photolysis, hydrolysis, volatilazation, sorption, biodegradation, biotransformation, to name a few. This report is basically a literature survey and summary of data available on many of the more important soluble hazardous waste constituents. It is an example of the type of data which is available in reference literature; a data bank which is constantly growing and improving. The reference scientific literature on the environmental fate of chemicals introduced into the environment should be researched on a real time basis to ensure that recent data is not overlooked. Much of these data are generated by sources which are not primarily interested in waste disposal rather than the effective and safe use of chemical products; and the best and most reliable information is often available only from the industry or industries which produce or market the chemical products.

(3) Migration in the unstaurated zone - §122.25(e)(4) & (5)

The definition of the migration pathway of leachate through the unsaturated zone required in §122.25(d)(3(ii) may be approximated as a vertical downward extension in each homogenious earth material formation in accordance with §122.25(e)(4). Special factors, i.e., boundry conditions and the effect of capillarity must however be be taken into account. The factors influencing the migratory pathway of gases have been described in the discussion on §122.25(d). §122.25(e)(5) merely confirms that the predictions are recognized to be "best estimates".

(4) Attenuation in the unsaturated zone - §122.25(e)(6)

The opportunity to ignore attenuation in the unsaturated zone is afforded by this paragraph. The factors which should be taken into account by a permit applicant who chooses either to account for or ignore attenuation are discussed in detail in the discussions on §122.25(d).

(5) Migration in the saturated zone - §122.25(e)(7)

This section requires that the factors of leachate uniformity, viscosity, specific gravity, and surface tension be taken into account in defining the leachate plume in the saturated zone; and that the empirical factor of dispersivity (spreading) be accounted for in the analysis.

(6) Maximum locational and rate definitions - §122.25(e)(8)

This section requires that the definition of the "zone of containment", which represents the extreme limits of the migration of leachate and gases which the applicant asserts will not be exceeded, be based on analysis taking into account the maximum mass rate of liquids expected to discharge from the facility, the maximum mass rate of of transport in the saturated zone, and the maximum rate of waste deposition into the facility. Uncertainty factors may be applied in the analysis, provided they are defined.

(7) Non-use withdrawal or collection - §122.25(e)(9)

By definition, Class A & B facilities will comply with the ground-water protection standard and no withdrawals for use will exist within the leachate plume. However, leachate may be migrating into wells installed in conjunction with the facility to control the migration of leachate or to remove historical contamination. If such wells do exist, the predicted quality of the water withdrawn must be accounted for. In addition, passive collection devices may be an outlet for ground water discharge. If passive collection devices exist within the zone affected by the leachate plume, the quality of any ground water affected by the facility which enters them must be considered.

(8) Discharges into surface waters - §122.25(e)(10)

The discharge of ground water affected by the leachate plume into surface waters is a major consideration for permit issuance. Prediction of the quality of such discharges are required. The predictions must consider the range of potential contaminants, and it must be shown that the upper limit of the range will be less that the maximum limit requested as a permit limit.

(9) Surface discharges - §122.25(e)(11)

If leachate discharge will occur to the ground surface or to standing surface waters (i.e., unclassified under the Clean Water Act) beyond the security boundry of the facility, a high degree of precision in predicting the quality of the discharge is required because of the inherent potental danger which could be associated with direct contact with leachate. The Agency considers such an occurance to represent a poor site location and would be inclined to prohibit facilities which would result in ground surface discharges if it were not for the fact that some leachates are quite innocuous.

(10) Ground water collection - §122.25(e)(12)

If leachate discharge will occur into a passive collection device, predictions of leachate quality must be made within the collection device and subsequent conveyance devices as well as at the outlet of the collection or conveyance device in the same manner as predictions are made with respect to discharges to surface waters. Passive collection and conveyance devices offer unique routes for human exposure, and must be carefully considered. In addition, the physical integitry of of the devises themselves must be considered.

(11) Withdrawal or collection for use - §122.25(e)(13)

If ground water affected by leachate will be collected for use, the quality predictions take on the greatest importance. For Class C facilities, which only affect ground water withdrawn for purposes other than drinking water use, quality predictions may be limited to those contaminants which can be expected to interfere with the particular use to which the water is put.

For Class D facilities, which will affect ground water withdrawn for public drinking water use, all of the contaminants which might occur in the ground water must be considered. Dilution of affected ground water by ground water unaffected by discharge may be taken into account.

For Class E facilities, which will affect ground water withdrawn for private drinking water use, all of the contaminants which might occur in the ground water must also be considered. Since private withdrawal of drinking water may be both itermittant and at very low rates, dilution of the affected ground water may not be considered.

(12) Summary

In §122.25(e) the Agency has attempted to offer flexibility in the degree of precision required in analysis, and in the level of detail required to comply with the informational requirements of §122.25(d). The required accuracy of prediction necessarily increases when the fact or potential of interference with the use of ground water is real and where the probability of unknowing exposure is high. It is expected that most permit applicants who can choose a site location will be able to avoid the more rigorous (and more uncertain) requirements for prediction. Owners and operators of existing facilities will not have this luxury of choice, but in most cases they will be able to be more precise in their commitments on maximum effects since those effects will already exist and be directly measurable.

The required predictions are recognized as "best estimates" and are periodically (triannually) subject to re-analysis based on monitoring and (if necessary) modeling. This technique of prediction and subsequent monitoring, modeling, and verification is intended to account for the inherent uncertainties that exist with respect to available predictive techniques and improve the understanding of the actual system performance with time. Uncertianty must be accounted for to assure that actual effects are within permitted maximums.

It should be noted that the published regulation included three codification errors. In §122.25(e)(1), the reference to §122.75(d)(1) should have read §122.25(d)(1); in §122.25(e)(2), the reference to §122.75 ahould have read §122.25(d)(2); and in §122.25(e)(2)(i), the reference to §264.19(d)(i) and (ii) should have read §264.19(a)(1) and (2). These codification errors are corrected in the following regulatory language.

D. Regulatory Language

(e) The precision of the definitions required in subsection (d) of this section may be varied in accordance with the need for information to establish compliance with the standards of this regulation as follows:

(1) The informational requirements of §122.25(d)(1) are applicable to all types and classes of land disposal facilities without exception.

(2) The informational requirements of §122.25(d)(2) are applicable to all types and classes of land disposal facilities however;

(i) for surface impoundments and waste piles, used solely for storage or storage and treatment which are designed to preclude leakage, as described in §264.19(a)(1) and (2), no definition of leachate discharge is required unless leakage is to be controlled by a leachate collection system.

(ii) for seepage facilities and injection wells which are designed and operated solely to introduce liquids into the land, leachate discharge can be considered equivalent to waste deposition unless the boundary conditions, between the liquid and the land, control the rate of discharge to a rate less than the rate of deposition.

(iii) for all types of facilities, the rate of gaseous escape which occurs directly to the atmosphere from any land disposal facility operational unit may be considered in conjunction with gaseous emissions from all operational units of the facility.

(iv) for all facilities from which leachate will discharge into the land, the informational requirements of §§122.25(d)(2)(i), (ii), and (iii) are to be considered as a best estimate of the volume and character of the leachate which will discharge from the facility into the land or be collected for treatment, discharge, or disposal from within or above materials emplaced to control the rate of leachate migration. Leachate discharge into the land will be subject to verification and more precise definition based on monitoring and modeling in accordance with §122.28(f).

(3) For any portion of the leachate which will discharge into natural earth material formations, the volume of discharge must be defined as precisely as possible; and the character of the leachate defined with sufficient precision to establish:

(i) The physical characteristics of the leachate to allow definition of the locus of leachate migration through natural earth materials including;

(A) the uniformity of the expected leachate (i.e. solubility and miscibility in ground water and constancy with respect to time). Immiscible portions of the leachate or substantially differing leachates must be considered independently.

(B) the range of viscosity of the leachate and immiscible portions of the leachate.

(C) the range of specific gravity of the leachate and immiscible portions of the leachate.

(D) the range of surface tension of the leachate and immiscible portions of the leachate.

(ii) The chemical characteristics of the leachate and immiscible portions of the leachate for the purpose of;

(A) discussing the expected or probable fate of the contaminants in the leachate based on independent study, or

(B) discussing the expected or probable fate of the contaminants in the leachate based on reliable reference sources of data.

(4) The informational requirements of §122.25(d)(3)(ii) may be approximated with respect to the extent of the zone in each homogenious natural earth material formation as a downward vertical extension of the overlying formation in contact with leachate provided;

(i) expansion of the zone of vertical migration due to boundary conditions between formations are accounted for, and

(ii) expansion of the zone due to capillary migration is accounted for.

(5) The informational requirements of §§122.25(d)(3)(iii) and (iv) are to be considered as a best estimate of the locus of gaseous migration in the land and through the land to the land surface.

(6) The informational requirements of §122.25(d)(4)(i) may be considered equivalent to the best estimates of §§122.25(d)(2)(i), (ii), and (iii) unless the permit applicant elects to define and

support the definition of;

(i) alterations of the chemical and/or physical characteristics of the leachate which will occur within the unsaturated zone.

(ii) the exchange capacity of the earth materials for contaminants in the leachate which will not be exhausted over the period that the facility will discharge leachate.

(7) The informational requirements of §122.25(d)(4)(iii) shall be defined taking into account the factors defined in paragraph (3)(i) of this subsection, the alteration of those factors which will occur due to mixing (for miscible leachates) with ground water, and factors to account for the dispersivity of the leachate in the specific natural earth material formations which will be contacted by leachate.

(8) The maximum locational definitions required in §§122.25(d)(3)(iv) and (4)(iv), termed the zone of containment; and the maximum rate definitions of §§122.25(d)(2)(iv) and (4)(v) shall be correlated with the maximum deposition rate definition of §122.25(d)(1)(iii). A defined factor may be applied to each of the maximum locational and rate definitions, except the maximum rate of deposition, to account for any recognized imprecision or lack of confidence in the analytical determinations of the maximums.

(9) No information is required under §§122.25(d)(5)(iii) or (iv) for Class A or Class B facilities unless leachate or ground water effected by leachate will be collected or withdrawn as a function of the facility design for treatment, discharge, or disposal; or passive collection devices such as storm sewers, sanitary sewers,

ditches, or agricultural drainage systems do or may in the future exist within the zone of containment.

(10) For any portion which will discharge directly or indirectly with ground water into surface waters; with sufficient precision to establish:

(i) the range of concentrations of contaminants, to be defined in accordance with §122.25(d)(5)(i), which could occur in the surface waters, and

(ii) that the upper limit of the range of concentration of contaminants is below that which is to be defined in accordance with §122.25(d)(5)(ii).

(11) For any portion which will discharge to standing surface waters or the surface of the ground, both of which should be avoided in a land disposal facility, it will be necessary to establish:

(i) as accurate a prediction as can be achieved unless,

(ii) the location of potential exposure to effects resulting from discharges to standing surface waters or the surface of the ground is part of the facility to which access is controlled in accordance with §264.14.

(12) For any portion which will be collected in a passive collection device and discharge to surface waters or to the surface of the ground, the precision described in paragraphs (10)(i) and (ii) of this subsection are sufficient provided the predictions include a definition of the range of concentration of contaminants which could occur within the collection device and be conveyed through or by the collection device and any subsequent conveyance device prior to discharge.

(13) For any portion which will be collected in a well or other ground water collection device and withdrawn for any use, with sufficient precision to establish:

(i) the range of concentration of contaminants, to be defined in accordance with §122.25(d)(5)(iii), which could occur in the ground water withdrawn; provided

(A) that for Class C facilities, the predictions may be limited to those contaminants which could occur over the range of withdrawal that may prevail and interfere with the specific uses to which the ground water may be put; and

(B) that for Class D facilities the predictions include, in addition to predictions for non-drinking uses in accordance with paragraph (A), predictions of the full set of contaminants which could occur over the range of rates of withdrawal that may prevail in ground water withdrawn and supplied for drinking use; and

(C) that for Class E facilities, the predictions include, in addition to predictions in accordance with paragraphs (A) and (B), predictions of the full set of contaminants which could occur in ground water withdrawn for private drinking use assuming no dilution of the affected ground water due to the rate of withdrawal, and

(ii) that the upper limit of the range of concentration of contaminants is below that which is to be defined in accordance with §122.25(d)(5)(iv).

4. Reports on hydrogeology, climatology, and geography - §122.25(f)

A. Proposed Regulation and Rationale

N/A

B. Summary of Comments

N/A

C. Discussion

See the preamble at 46 FR 11151-52

D. Regulatory Language

(f) A report on the hydrogeology, climatology, and geography of the area where the facility is to be located which that be based on the site investigation requirements in paragraph (g) and that shall include;

(1) A description of the geology and hydrology of the area and a listing of all pertinent published and open file text material and mapping available from the United States Geological Survey, the Soil Conservation Service, and State Geological Agencies. Text material and mapping from such public sources relied upon in preparing the description shall be referenced, and that which was not relied upon shall be discussed with reference to the reasons it was not used. Any other published or unpublished text material or mapping used in preparing the description shall also be referenced. The description shall;

(i) include such mapping as is necessary to ensure an understanding of the geology and hydrology by a lay reviewer (e.g., a member of the public at large rather than a peer) of the description.

(ii) be of sufficient detail to define the various earth material formations in the vicinity of the site and to serve as a basis of confirming predictions of the transverse, lateral, and vertical migration of infiltrating rainwater, any liquids to be disposed of or generated within the facility, hazardous wastes or any other wastes disposed of within the facility, or the decomposition byproducts of such hazardous wastes of other wastes that define the zone to be affected within the zone of containment.

(iii) include the logs of borings taken to establish or improve the understanding of the geology and the hydrology of the area to be impacted by the waste disposal activity.

(iv) include mapping to define ground surface contours, consolidated rock contours, and ground water elevation contours.

(v) include a description of any changes in ground surface contours, consolidated rock contours, and ground water elevation contours that will result from the construction or operation of the facility.

(vi) include a description of the character of each earth material formation expected to be contacted by leachate or gases with regard to; type of material, uniformity, permeability, porosity, weathering (of consolidated rock), fracturing (of consolidated rock and clay), fault zones (of consolidated rock), karst zones (of consolidated rock), and swelling (of clay).

(vii) include a description and such mapping of the progression of the migration of the leachate plume in the ground water flow system during the active life of the facility, during the post-closure care period and, unless the plume discharges to surface water or it can be shown that the plume will be collected or withdrawn, subsequent to the post-closure period. The mapping shall be adequate to ensure an understanding of the locus of the migration of the leachate plume by a lay reviewer of the description.

(2) A report on the climatologic factors based on the data required in paragraph (g)(2).

(3) A report on the geographic factors based on the data required in paragraph (g)(3).

5. Site investigation requirements - §122.25(g)

ISSUE: "Geologic and hydrologic factors" - §122.75(g)(1)

A. Proposed Regulation and Rationale

N/A

B. Summary of Comments

N/A

C. Discussion

(1) Topographic expression

The topography of the site should be expressed via contour mapping. Such maps are based on on-site vertical and horizontal controls to represent all pertinent elevations and locations (i.e., to establish the spatial configuration of a HWMF site). Such controls (e.g., stone monuments) are described in publications available from the U.S. Geological Survey, U.S. Coast and Geodetic Survey, and State Geologic Surveys for most areas of the U.S. Topographic is indicative of the direction of ground-water flow in an area, since unconfined flow may roughly simulate the topography. Topography also defines surface drainage patterns, which is related to unconfined ground-water flow conditions (e.g., flow direction).

Drainage patterns can be correlated with bedrock distribution, the attitude of stratiform rocks, the arrangement of surfaces of weakness (e.g., joints and faults), and other structural features. Topography can also reveal Karst terrain features.

Contour intervals on topographic maps are selected in relation to the relief in the given area (e.g., smaller contour intervals for flatter areas and larger contour intervals for highly sloped areas). If the available contour maps do not provide the degree of topographic detail necessary to adequately express the relief in the given facility area (i.e., the contour interval is greater than 2 meters) or a contour map is not available, then established surveying methods can be employed to obtain the data needed to construct topographic maps for portions of of the site area where it is needed (e.g., Lahee, 1961, Chapter 16).

(2) Characterizing unconsolidated earth materials

Knowledge of the properties of the unconsolidated earth materials in the site area is necessary to determine the locus of migration of a facility discharge to reach the uppermost aquifer. Also, properties of any unconsolidated materials should be ascertained as a sound engineering practice where such materials will be subject to loads or used as a functioning part of a constructed facility. The type of material (e.g., clay, mud, sand, gravel) and its uniformity (i.e., areal extent and thickness) in the area of the site can be established from information obtained from existing and/or new borings. Records of existing boring data may be obtained from governmental agencies (e.g., State Geological Survey) or from private sources (e.g., drilling and boring contractors and well drillers). Material type can be identified in the field by qualifed professionals and in the laboratory by instrumental methods (e.g., Asphalt Institute, 1969, pp. 189-190). Determinations of specific properties (e.g., permeability, porosity, and fracturing) of these materials, coupled with their uniformity and distribution, yields information which can be applied in predicting the likelihood and preferential path of a facility discharge to ground water. In such predictions, the attainment of field capacity in the uppermost earth materials must be accounted for. (Methodology for determining or describing permeability, porosity, and fracturing are discussed further under "Characterizing consolidated rock").

Borings can be drilled using various methods, each method affecting the degree of disturbance (reliability) of the obtained earth material sample (e.g., Lahee, 1961, pp. 602-607; Johnson, 1975, pp. 163-166). Correlation of data from boring samples is used to construct subsurface maps to define geologic structure. This can be accomplished through comparisons of analyses of field samples and through other surveying (logging) techniques, such as electrical logging and micrologging, sonic logging, and radioacitve logging (e.g., Lahee, 1961, pp. 611-628).

Unconsolidated earth materials (i.e., soils) may serve as a functioning part of a constructed facility and may be subject to loads. For this reason, swelling, settlement (i.e., compressibility) and plasticity of these materials should be determined.

Swelling (or shrinking) phenomena refer to volume change deformations which occur in soils, independent of any externally applied load (Asphalt Institute, 1969, p. 14). Swelling and shrinking are most pronounced in fine grained soils, especially clays. Both swelling and shrinking processes result from a build up and release of capillary tensile stresses within the soil's pore water and the varying degree of affinity for water which certain clay minerals have (e.g., Asphalt Institute, 1969, p. 14). Most high volume change soils in the U.S. occur in belts or regions that are well known to most soil scientists. Knowledge of the swelling (or shrinking) properties of a given soil is used to determine the potential effects that such natural deformations will have on the physical integrity of a facility structure and therefore the reliablity of its designed waste management function. Laboratory tests are available to measure the swelling or shrinking properties of soils (e.g., Asphalt Institute, 1969, Chapters VIII and X).

The *settlement* of unconsolidated earth materials arises primarily from a change in its structure accompanied by the expulsion of air or water, or both (Asphalt Institute, 1969, p. 13). Compressibility and compaction are terms which denote such volume change deformations in soil. Compressibility is influenced greatly by soil structure and the past stress history of the deposit. Deposits developed through sedimentation usually are more compressible than their residual or wind-blown counterparts (Asphalt Institute, 1969, p. 13). It is important to determine the degree of settlement a facility will cause to evaluate the potential impact to the facility's structural integrity. Laboratory methods for determining the relative compressibility of most soils have been devised and are widely used (Asphalt Institute, 1969, p. 13).

The plasticity of a material refers to its ability to be deformed rapidly without cracking or crumbling and then maintain that deformed shape after the deforming force has been released (Asphalt Institute, 1969, p. 11). "This non-reversible, or plastic, deformation is probably the sum of a large number of small slippages at grain-to-grain contact points and minute local structural collapses throughout the soil mass" (Asphalt Institute, 1969, p. 11).

"It has been reasoned that as the plastic deformations in a soil become larger under the action of increasingly greater applied loads, a reorientation of soil particles begins to take place in certain critical zones within a soil mass. When the loads have become sufficiently large and a sufficient number of the soil particles in this critical zone are, perhaps, oriented parallel to one another, the soil mass begins to fail in shear within these critical zones. At or near this point the shearing resistance or strength of the soil is said to have been exceeded" (Asphalt Institute, 1969, p. 11-12). Methods for determining plasticity are found in the literature (e.g., Asphalt Institute, 1969, pp. 210-211). Determining the plasticity of the soil, therefore, has important implications to the structural integrity of a facility, especially when load conditions would exceed the shearing strength. This could lead to a rupture of "rigid" facility components resulting in unintended discharges of waste materials.

(3) Mapping of contact surfaces

Contour mapping of the contact surface between consolidated (i.e., bedrock) and unconsolidated earth materials is important where leachate migration is expected to reach such a contact.

Bedrock at this contact can act as a retarding surface upon which ground water will accumulate forming a water table in the unconsolidated materials above. Hence, knowledge of the contour of the contact surface is essential to determine ground water or leachate flow direction in the site area. Data for mapping contact zones can be obtained through various instrumental procedures, including air photography (e.g., Lahee, 1969, Chapters 16 and 17). Since such contacts are hidden from view, the investigator must make use of borings and bedrock outcrops in such studies. Contacts hidden under surface debris may also be located by observing the distribution of rock chips and fragments in the soil derived from the underlying bedrock (Lahee, 1969, pp. 426-427). Contouring of contacts employs the same principles as those for surface contouring (e.g., establishing horizontal and vertical controls). Precision in locating contact zones buried under a soil mantle involves special considerations that are dependent on (1) the inclination of the ground; (2) the thickness of the soil cover; (3) climatic conditions; (4) the trend of the contact line; and (5) the regularity of the contact (Lahee, 1969, p. 426). Various types of contacts (e.g., eruptive, sedimentary) are evaluated using similar techniques, but special considerations should be recognized in different situations (Lahee, 1969, pp. 422-440).

(4) Characterizing consolidated rock

Where leachate migration will occur within consolidated rock, such rock must be subject to a geologic investigation. Material type can be determined from analysis of boring data, as for unconsolidated materials. Porosity can be determined on boring samples in the laboratory by standard techniques (e.g., Freeze and Cherry, 1979, p. 337). Such porosity determinations are applicable to materials in both the unsaturated and saturated zones. Permeability (i.e., hydraulic conductivity) of earth materials may be determined by laboratory and field methods. Permeabilities of boring samples (from the saturated or unsaturated zones) can be determined in the lab by constant-head or falling-head permeameters, consolidation tests, and by methods based upon grain-size distribution (e.g., Freeze and Cherry, 1979, pp. 335-339, pp. 350-352). The accuracy of permeability values obtained are dependent upon the nature of the material (e.g., sand and gravels) and the degree of disturbance of the sample (e.g., cuttings versus intact cores). For earth materials in the saturated zone, permeabilities may be determined by field methods (e.g., piezometer tests, pumping tests and borehole dilution tests)(Freeze and Cherry, 1979, pp. 339-350, pp. 428-430).

Where consolidated rock (bedrock) is overlain by a mantle of unconsolidated earth materials, the relationship between these formations must be established. Such study should consider whether the mantle is residual (formed in situ) or has been transported. Such knowledge can aid in determining the type of underlying bedrock as well as in delineating the contact surface. The contact surface may be difficult to delineate when the mantle is residual due to the gradational effects caused by weathering processes.

Where consolidated rock lies near or is exposed at the earth's surface, information can be obtained which is of use in predicting leachate migration potential. Examination of the effects of weathering and erosion (e.g., formation of Karst features such as sinkholes) not only helps to identify the nature of the bedrock materials (e.g., limestone), but also reveals potential pathways for leachate flow. It should be recognized that determining the direction(s) of leachate flow in Karst terrain can be quite difficult due to the randomness in the orientation of solution flow channels in the subsurface. Conversely, Karst features may provide data on subsurface structure, a factor which can influence leachate flow direction (e.g., in regions where limestone strata, near the surface of the ground, are horizontal or low-dipping, numerous sinkholes, arranged in a row, may indicate the position and trend of faulting) (Lahee, 1961, p. 365). Karst features can often be identifed on topographic maps available from the sources mentioned earlier.

Knowledge of *fractures* (i.e., joints and faults) in consolidated (and unconsolidated) earth materials is crucial to any site investigation for predicting the potential migration of leachate (or gaseous) discharges from a HWMF. A *fault* may be defined as a fracture along which there has been slipping of the contiguous masses against one another (Lahee, 1961, p. 222). Solid rocks or unconsolidated sands, gravels, etc. may be dislocated in this way. A fault normally dies out at its two ends. Measured displacements vary from microscopic to many miles, and in length faults range from microscopic to hundreds of miles (Lahee, 1961, p. 223). Various kinds and degrees of displacement are possible depending upon the directions and intensities of the causative forces. Faults are classified according to: (1) the nature of their displacement; (2) their distribution; and (3) their relations to disrupted bedding or other parallel structures (Lahee, 1961, pp. 232-245). Evidences for faulting can be obtained by observing slickensides or other marks of slipping which have been exposed (i.e., by observing the rock structures on the two sides of the faults) and by examination of topographic expression. Methods for making such observations appear in the literature (e.g., Lahee, 1961, pp. 245-268).

Joints are well defined cracks in a rock, where there has been no or only a very small amount of slippage between the blocks. Joints are the most common kind of fractures in rocks. They are important in promoting erosion since they serve as channels for waters that cause disintegration and in glacial quarrying, and inviting concentrated attacks by abrasive agents (Lahee, 1961, p. 282). Joints display a great variety of characteristics and are classified in regard to the type of force which created them (e.g., compression, tension, torsion). Joints may occur in unconsolidated and consolidated earth materials (e.g., clay and shale). Information on methods of identifying joints and interpreting their characteristics in various geologic settings are discussed in the literature (e.g., Lahee, 1961, pp. 270-282).

Other processes leading to cracks in consolidated rock are fracture cleavage along certain parallel rock surfaces (minute displacements in which the blocks are thin sheets); and brecciation (resulting in rock which is intersected by closely spaced joints). Descriptions of field identification of these features are given in the literature (e.g., Lahee, 1961, pp. 282-286).

The location and character (e.g., type, age, activity, displacement magnitude and direction) of fault zones must be investigated for potential adverse impacts to HWMF operations (e.g., potential to impair a facility's structural integrity or causing unfavorable or undefinable routing of a facility discharge). Information on the locations of fault zones is available from the USGS (e.g., N.A. Howard, et al, 1978).

In investigating consolidated rock, it is important to understand the relationships between adjacent consolidated formations (in both vertical and horizontal directions). Such relationships could have a bearing on the pathway of a facility discharge migrating in ground water (e.g., a sandstone aquifer overlying a relatively impermeable igneous rock) and should be determined through standard geological methods (e.g., examining boring samples and electrical logging). Another example is the changing earth material characteristics associated with transgression and regression of sediment deposits in coastal areas or piedmont deposition by rivers (Lahee, 1961, pp. 77-82). Such depositional processes result in changing characteristics (e.g., permeability and porosity) in both vertical and horizontal directions. Also, unconformities (i.e., interuptions in the expected sedimentary sequence due to erosion) must be noted, as they can affect the predicting of discharge migration (e.g., through lateral variations in texture, porosity and permeability). Methods for field interpretation of data for sedimentary, igneous and metamorphic rocks (and their inter-relationships) are presented in the literature (e.g., Lahee, 1961, Chapters 5-9).

In order to describe the position (i.e., the attitude) of an earth material formation, its "dip" (the maximum angle of slope of the surface) and its "strike" (the direction of the intersection of the surface with any horizontal plane) must be measured. Determination of attitude can be applied to different types of earth material formations (e.g., consolidated and unconsolidated) and can also be used to measure contortions or structural features within these formations (e.g., folds, fault faces, plunging folds). Knowing the attitude of an earth material formation and the characteristics of the material (e.g., thickness, permeability, porosity, fracturing, etc.) is essential in predicting the fate of a discharge from a HWMF. Field methods for determining attitude are well established geological investigation procedures (e.g., Lahee, 1961, pp. 748-752, Chapters 15-16).

In order to predict the fate of a facility discharge, information must be obtained to determine the ground-water flow direction and rate. An early step in this process is to determine ground-water elevations (i.e., hydraulic heads) in order to construct a water table or potentiometric surface contour map. This is accomplished through the installation of piezometers which are narrow wells which measure the hydraulic heads at given points in an aquifer. Methods of designing and installing piezometers are presented in the literature (e.g., Fenn, 1977, pp. 86-90). Hydraulic head data can be measured by various techniques (e.g., National Water Well Association, 1975, pp. 116-117). In order to determine the directions of ground-water flow, several piezometers must be installed. By obtaining hydraulic head data from several piezometers, it is possible to contour the positions of equal hydraulic head by constructing equipotential lines. Then, flowlines can be constructed perpendicular to the equipotential lines (in the directions of the maximum potential gradient), forming a _flow net_. Detailed instruction on flow net construction is presented in the literature (e.g., Freeze and Cherry, 1979, Chapter 5). Flow net analysis, performed on a periodic basis, can reveal changes in flow directions induced by natural or human causes (e.g., ground-water mounding beneath a HWMF, ground-water depression due to pumpage, and changes in amounts of natural recharge). The interpretation and usefulness of flow nets of regional ground-water flow is discussed in the literature (e.g., Freeze and Cherry, 1979, Chapter 6).

New borings or new wells drilled to gather subsurface data during a site investigation must be properly "abandoned" after serving their purpose. Such holes, if not filled (or plugged and sealed, if necessary), may become paths for contaminant migration to ground water from the land surface and/or via interaquifer exchange. Ground-water contamination through such mechanisms has been reported in the literature (e.g., Gass, et al, 1977). Methods to properly fill, plug and seal wells (e.g., plugging with cement, sand and cement grout, and concrete) are explained in various publications (e.g., National Water Well Association, 1975, pp. 133-142; Smith, 1976, Chapter 10).

Site investigations, through field surveys, must locate and describe all existing excavations, borings, wells or other ground-water collection devices within the "zone of containment" of facility discharges. This information is needed when predicting the fate of facility discharges with respect to potential impacts upon ground-water supplies and the effects of withdrawals on the migration pattern of a discharge plume (e.g., effects of a pumping supply well on plume geometry and migration rate).

D. Regulatory Language

(g) Site Investigation Requirements. Each applicant for a permit for a hazardous waste facility shall investigate the site and environs of the storage, treatment, or disposal activity and establish permanent on site vertical and horizontal controls to allow all elevations and locations to be surveyed, expressed, and plotted with reference to USGS and USC&GS horizontal and vertical controls.

(1) With respect to geologic and hydrologic factors;

(i) Surface topography shall be surveyed with sufficient accuracy to allow the plotting of surface contours at a contour interval not greater than two meters over an area extending at least forty meters beyond any proposed construction activity, including excavation or filling, or any area where leachate will migrate within ten meters of the ground surface.

(ii) Unless reliable boring data is available from previous investigations, sufficient borings shall be made in unconsolidated earth materials in the vicinity of the site and the zone of leachate or gaseous migration to characterize or verify the characterization of unconsolidated earth materials with respect to type of material, uniformity, permeability, porosity, and fracturing. In addition, where such materials will be subject to loads or used as a functioning part of a constructed facility; swelling, settlement, and plasticity shall be characterized or verified.

(iii) Where leachate migration will reach the contact surface between unconsolidated and consolidated earth materials, the contact surface of consolidated rock shall be surveyed with sufficient accuracy to allow the plotting of the contact surface at a contour interval of not greater than four meters.

(iv) Where leachate migration will occur within consolidated rock, the effected consolidated rock shall be characterized by geologic investigation with respect to type of material, permeability, porosity, relationship to any overlying mantle of unconsolidated materials, relationship to adjacent consolidated materials, degree of weathering including the formation of karst zones, degree of fracturing, the location and character of fault zones, and attitude.

(v) Ground water elevations shall be determined with sufficient accuracy to allow the plotting of water table contours at a contour interval of not greater than two meters beneath the site where ground water mounding may or will occur due to discharge from the facility, and in any area where ground water affected by leachate will migrate within ten meters of the ground surface. Beyond the above described areas, sufficient ground water elevation data shall be obtained to construct a ground water flow net for any given set of conditions of discharge to the ground water, withdrawal or discharge from the ground water, and recharge of the ground water which may occur prior to, during, or after the active operation of the facility.

(vi) To the extent that new borings are made or new wells are installed to obtain the data necessary to characterize or verify the character of earth materials or the ground water within and flowing through such earth materials, boring holes and wells shall be filled and, if necessary, plugged and sealed to avoid creating new paths for fluid migration unless the hole or well will be maintained as a ground water sampling well in accordance with Subpart F.

(vii) All existing excavations, borings, or wells or other ground water collection devices within the zone of containment shall be located by field survey, and described in detail.

ISSUE: "Climatologic Factors" - §122.25(g)(2)

A. Proposed Regulation and Rationale

N/A

B. Summary of Comments

N/A

C. Discussion

Climatologic factors must also be considered when performing a site investigation. Knowledge of seasonal variation in ambient temperatures (including the average monthly temperature and the extremes during any month) are helpful in determining the likelihood of contaminant movement to or through earth materials. Temperatures low enough to cause freezing of the uppermost earth materials may temporarily retard infiltration or elevated temperatures in the location of a facility may produce a preferential route of liquid migration. Wind conditions (including the average number of days in any direction and at any velocity range for which data exists, and the direction and velocity of expected extremes) should be determined. Such data is used to predict migration patterns of any gaseous emissions from a HWMF. Seasonal variation in the type, duration, intensity, and amount of precipitation (including monthly averages and the expected extremes during any month) should be ascertained since such data are needed to estimate leachate formation for contaminant migration predictions. The required climatological data is available from the U.S. Weather Bureau for all localities within the U.S.

A water balance for the HWMF site area being investigated manipulates precipitation data and other hydrologic factors - run-off, infiltration and evapotranspiration - to determine the amount of percolation (i.e., how much of the precipitation would actually recharge the ground water). Water balance determinations should be performed using annual data and data for other intervals which could represent operating extremes. Water balance methodology is described in the literature (e.g., Fenn, et al, 1975; Thornthwaite & Mather, 1955 and 1957).

D. Regulatory Language

(2) With respect to climatologic factors;

(i) The seasonal variation in ambient temperatures including the average monthly temperature, and the extremes during any month.

(ii) The seasonal variation in wind conditions including the average number of days in any direction and at any velocity range for which data exists and the direction and velocity of expected extremes.

(iii) The seasonal variation in the type, duration, intensity, and amount of precipitaion including both monthly averages and the expected extremes during any month.

ISSUE: Geographic Factors - §122.25(g)(3)

A. Proposed Regulation and Rationale

N/A

B. Summary of Comments

N/A

C. Discussion

See the preamble at 46 FR 11152

D. Regulatory Language

(3) With respect to geographic factors;

(i) The type of land use including but not limited to:

(A) the associated densities of human population living, working, or passing through the area.

(B) the associated density of animal population living in or passing through the area.

(C) the associated intensity of use for the production of food chain crops.

(ii) The controls over land use and the manner in which such controls are implemented or are to be implemented.

(iii) Projected future land use based on trends in land use, existing or developing plans to modify the land use.

ISSUE: Special requirements based on land disposal facility class - §122.25(g)(4)

A. Proposed Regulation and Rationale

N/A

B. Summary of Comments

N/A

C. Discussion

D. Regulatory Language

(4) With respect to the following special requirements based on land disposal facility class:

(i) An applicant for a permit for a Class A land disposal facility must investigate the entire aquifer to which discharge will occur and within which leachate will migrate and establish, based on reliable reference data or independent field investigation, that;

(A) no part of the aquifer is now or will in the future be used as a source of water supply for domestic, agricultural, industrial, or commercial uses.

(B) no migration can occur from the aquifer to any other aquifer.

(ii) An applicant for a permit for a Class B land disposal facility must investigate the entire portion of the aquifer to which discharge will occur and within which leachate will migrate (which may be equivalent to or inclusive of the zone of containment) and establish, based on reliable reference data and/or independent field investigation, that;

(A) no part of the portion of the aquifer is now or will in the future be used as a source of water supply for domestic, agricultural, industrial, or commercial uses.

(B) no migration can occur from the portion of the aquifer to any other portion of the aquifer or to any other aquifer.

(iii) An applicant for a permit for a Class C land disposal facility must investigate in detail each location of ground water withdrawal or collection for use, referencing well logs or construction records when available, with respect to the type of well or other ground water collection device including;

(A) the age of the well or collection device, the materials of construction, and the location of casings, screens, seals, plugs, etc.

(B) the zone of collection or withdrawal.

(C) the rate of ground water collection or withdrawal.

(D) the possible yield of the well or other ground-water collection device.

(E) the actual use of the collected or withdrawn ground water.

(iv) An applicant for a permit for a Class D land disposal facility must, in addition to the requirements of paragraph (iii) for any ground water use other than public drinking water, investigate each location of ground water withdrawal or collection for use as public drinking water, referencing well logs or construction records when available, with respect to the type of well or other ground water collection device including;

(A) the age of the well or collection device, the materials of construction, and the location of casings, screens, seals, plugs, etc.

(B) the zone of collection or withdrawal.

(C) the rate of ground water collection or withdrawal.

(D) the potential yield of the well or other ground water collection device.

(E) the physical potential yield of the aquifer to additional wells or other ground water collection devices in the same zone of withdrawal.

(F) the treatment provided prior to distribution of the ground water for use.

(v) An applicant for a permit for a Class E land disposal facility must, in addition to the requirements of paragraph (iii) for any ground water use other than public drinking water and the requirement of paragraph (iv) for any ground water use as public drinking water, investigate each location of ground water withdrawal or collection for use as private drinking water, referencing well logs or construction records when available, with respect to the type of well or other ground water collection device including;

(A) the age of the well or collection device, the materials of construction, and the location of casings, screens, seals, plugs, etc.

(B) the zone of collection or withdrawal.

(C) the rate of ground water collection or withdrawal.

(D) the possible yield of the well or other ground-water collection device.

(E) the physical potential yield of the aquifer to additional wells or other ground water collection devices in the same zone of withdrawal.

(F) the alternative sources of public or private drinking water available to the well owner.

6. Description of monitoring and modelling - 122.25(h)

A. Proposed Regulation and Rationale

N/A

B. Summary of Comments

N/A

C. Discussion

See the preamble at 46 FR 11153. Note that the preamble discussion erroneously refers th §122.25(g).

D. Regulatory Language

(h) A description of the monitoring and, if planned or required, the modeling proposed to comply with Subpart F (Ground Water and Gaseous Emission Monitoring) or to verify or refine the projections of the transverse, lateral, and vertical extent of the migration of and the mass of contaminants in the leachate, the lateral and vertical extent of the migration of gases, and the mass of gaseous emissions.

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